Production Research Report No. 113

CULTURAL and HARVESTING METHODS for KENAF . . .

AN ANNUAL CROP SOURCE OF PULP IN THE SOUTHEAST

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

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CULTURAL AND HARVESTING METHODS FOR KENAF . . . AN ANNUAL CROP SOURCE OF PULP IN THE SOUTHEAST

By

G. A. White, *leader*, Chemurgic Crop Investigations, Crops Research Division, Beltsville, Md.

D. G. Cummins, *associate professor*, Univ. of Georgia, Experiment.

E. L. Whiteley, *associate professor*, Texas A & M Univ., College Station.

W. T. Fike, *associate professor*, North Carolina State Univ., Raleigh.

J. K. Greig, *associate professor*, Kansas State Univ., Manhattan.

J. A. Martin, *associate professor*, Clemson Univ., Clemson, S.C.

G. B. Killinger, *agronomist*, Univ. of Florida, Gainesville.

J. J. Higgins, *plant physiologist*, Crops Research Division, Glenn Dale, Md.

T. F. Clark, *head*, Fibrous Products Investigations, Northern Utilization Research and Development Division, Peoria, Ill.

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CONTENTS

CULTURAL AND HARVESTING METHODS FOR KENAF . . . AN ANNUAL CROP SOURCE OF PULP IN THE SOUTHEAST

SUMMARY

Kenaf is a promising new U.S. crop source of raw material for pulp. It is a fast-growing, productive plant with fairly wide adaptation. Excellent, high-yielding pulps are easily obtained.

Traditionally, kenaf is known as a cordage crop or jute substitute. Research on kenaf in the United States as a cordage crop resulted in the development of high-yielding, anthracnose-resistant varieties. Field trials to test its potential as a pulp crop first started in 1957. Yields from early tests were generally low; but as tests were made in more southerly areas, improvements were made in cultural practices and yields increased. By 1965 the areas of adaptation without supplementary water were low-elevation sections of Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and eastern Texas. High yields have been obtained as far north as Indiana, Iowa, Kansas, and Nebraska. Excellent yield potentials should exist in warm, dry areas with irrigation.

Kenaf, a member of the Malvaceae family, may grow 8 to 20 feet tall and is largely unbranched in thick stands. Late-maturing varieties require short days for floral initiation. The large, creamy-white flowers are borne in leaf axils. The seeds weigh about 25 grams per 1,000. Leaves of the variety Everglades 71 are deeply lobed (split) but those of Everglades 41 shallowly lobed (entire). These varieties were developed in Florida.

Cultural methods vary with the area. In general, early planting while soil moisture conditions are favorable is recommended. Late April or early May dates are satisfactory for most areas of the Southeast and Kansas, but earlier planting is suggested for northern Florida and the southern part of the kenaf-growing area. Farther north, planting should be delayed until the time soybeans can be planted. Seed should be of high germination (80 percent or better). Uniform seed droppage and coverage of ½ to 1 inch are essential for uniform, rapidly emerging stands. A seeding rate of 6 to 8 pounds per acre is sufficient for most plantings. Seeds can be planted with regular corn or soybean planters or with grain drills. The narrow (20- and 30-inch) planting and cultivating equipment should be exceptionally well suited for kenaf.

Since no herbicides have been registered for use on kenaf, rows wide enough for cultivation are recommended. Bedded rows may be necessary for areas with high water tables. Kenaf thrives under conditions of high temperatures and abundant soil moisture, but will not long tolerate standing water or water-logged soils. A final plant population of 75,000 to 100,000 plants per acre is ample for the warm areas, but somewhat higher populations may be required in the North to compensate for decreased plant height. On moderately fertile soils, 75 to 100 pounds of nitrogen per acre is recommended either as a preplant application or half preplant and half sidedressed. On lighter, infertile sandy soils, such as the Florida flatwoods soils, much higher rates, including one or two sidedresses of nitrogen, will be required for high yields.

No known diseases or insect pests seriously injure kenaf. The better known Cuban, Floridian, and Guatemalan varieties are resistant to the serious disease, anthracnose.

Kenaf is a fast-growing, competitive crop, but chemical weed control measures would be very desirable in most potential production areas. No weed control (not even cultivation) has been necessary for wide, bedded rows in the Florida flatwoods soils. More research is needed to determine which herbicides will control weeds effectively without damaging kenaf.

The most serious production pests are nematodes. Kenaf is highly susceptible to root-knot nematodes and other nematode species. Breeding

efforts to develop nematode-resistant varieties need to be intensified. Resistance may be obtained (1) through crosses of cultivated types with wild accessions that are found to be resistant by screening and (2) through hybridization of kenaf and roselle. Several lines of roselle, a slower growing plant than kenaf, have a high level of nematode resistance. A small population of hybrids between kenaf and roselle has been obtained. The development of distinct "pulp" varieties should concurrently be combined with efforts to incorporate nematode and disease resistance into productive varieties. Until new varieties with superior yield and resistance are available, the variety Everglades 71 is recommended. Through the years, yields of Everglades 71 have consistently been greater than those of other varieties.

Kenaf generally appears to be competitive for acreage with corn and soybeans, and in some agricultural areas with cotton. Under favorable conditions, yields of 6 tons or more per acre (dry basis) should be obtained in most of the Southeast. Further testing for yield potentials is needed in areas involving different soil types. In northern Florida, field-scale yields of 7.5 to 8.0 tons per acre have been obtained. Experimental yields on replicated, small-plot basis have been as high as 20 tons.

Preferred systems of harvesting, handling, and storing kenaf remain to be worked out. From the standpoint of suitability and availability, field chopping with forage harvesters appears feasible. Heavy-duty choppers, preferably with a cylinder-type chopping action with row headers, will satisfactorily harvest kenaf, even with plants 20 feet tall. Cutter-bar headers will handle narrow-row material if plant height is 10 feet or less. Where postfrost conditions are favorable to field drying, the standing crop may be chopped when plants have dried out enough for safe storage. The air-dried chopped material may be stored in large uncovered or covered piles. Where drying conditions are unfavorable, such as in northern Florida, the crop may have to be harvested green and the chopped material stored like silage, in large water-filled tanklike structures or possibly in air-tight plastic enclosures. Ensiled material has shown good pulping characteristics. Because of different climatic conditions and mill requirements, procedures for harvesting, handling, and storage will vary.

Utilization studies on composition, fiber dimensions, pulping processes, and kenaf–wood blends have been conducted. Kenaf contains less lignin, crude cellulose, and alpha cellulose than either softwoods or hardwoods but about twice as much pentosans as softwoods. Fiber dimensional characteristics of kenaf stalks are intermediate to those of softwoods and hardwoods. Blending results indicate good possibilities for kenaf–wood pulp blends in various types of papers. More research using kenaf in selected blends and as total furnishes for specific types of paper is needed. Kenaf should prove to be a versatile raw material for various pulping applications. Its suitability as a versatile pulping material coupled with desirable agronomic attributes shows kenaf to be a very promising new crop prospect.

INTRODUCTION

Kenaf (*Hibiscus cannabinus* L.) is an important world crop source of textile fiber for manufacture of twine, bagging, rope, rugs, and other products. Only the bast or outer bark fibers are used. Kenaf is frequently grown as a backdoor crop for fiber and the more tender upper leafy portion of the plant is sometimes used for food. Known by many names, kenaf has become an important jute fiber substitute. The crop was grown in Florida for bean poles on about 1,500 acres in 1967 and 1968, and acreage in 1969 is expected to be larger.

A little more than a decade ago (1957), kenaf was recognized as a possible source of cellulosic fiber for pulping. Stems of kenaf plants contain two distinct fiber types—the bast or outer bark fiber and an inner thick core of short, woody fibers, both of which may be utilized in pulp. In view of good cropping characteristics and technological suitability as a pulp source, kenaf is a very promising potential new crop for the United States, particularly in the southeastern part of the country. Much interest in this productive, new pulp

source has been generated in the pulping industry.

Why, when wood is seemingly abundant and is used in more than 95 percent of the pulp produced, are we interested in an annual crop source of pulp?

First, kenaf, under favorable conditions, may be several times more productive than trees on a per acre per year basis. Much of the land in the Southeast that is periodically cleared by pulp companies is suitable for kenaf production. More efficient use of land may be possible by producing kenaf.

Second, although there is no overall shortage of wood in the United States, already there are local shortages of hardwood. Thus, as new mills are built and per capita consumption increases along with additional pulp export opportunities, these shortages are expected to become more critical and widespread.

Third, most farmers are inclined to grow crops that provide annual returns. This means that farmers tend to plant nontree crops on cleared land.

Crane (*18*)[1] and McCann (*30*) have reviewed the literature on kenaf. Corkern (*15*) prepared a bibliography for 1950–62. Two international conferences on kenaf brought information together on all facets of kenaf production and utilization (*59*, *60*). In the first proceedings mention was made that kenaf showed promise as a raw material for papermaking. In the second proceedings a few papers dealing specifically with kenaf as a pulp crop were presented.

Representatives from State experiment stations, from U.S. Department of Agriculture agencies, and from more than 40 pulp and equipment companies met at Gainesville, Fla., for a conference on kenaf from Oct. 31 through Nov. 1, 1967. The objective of the meeting was to exchange information on cultural, harvesting, handling, processing, and pulping methods for kenaf. The proceedings of the conference updates previous information (*58*). Gray (*23*) emphasized that a number of factors may make it difficult for the Southern United States to provide a substantial increase in wood for pulping at acceptable prices or in earnings on land and tree farming investments. He suggested that the pulping industry, especially those companies that either have an inadequate land base or are in an area with moderate to intense competition for available wood, may have great interest in supplementing wood supplies with nonwood fibers such as kenaf. The industrial representation at the conference attested to the interest in such materials.

PULPWOOD CONSUMPTION AND SUPPLY OUTLOOK

Frequent and continuing appraisals of cellulosic fiber resources and the factors related to their consumption in the United States have been made by several groups over a long period. These appraisals provide evidence of the importance of cellulosic fibers, and pulpwood in particular, in the national economy. There may be limits in the ability of this country to satisfy the projected needs for cellulosic fibers; some projections indicate that limits may be realized within the period from 1980 to 1990. According to a 1966 Food and Agriculture Organization (FAO) report (*1*), the annual world consumption of paper and paperboard will increase more than twofold, from 77 to 162 million metric tons (2,205 pounds), in the period from 1961 to 1975. Consumption by the United States would account for about 20 percent of the increase, which will be largely met by domestic sources. This would mean the additional use of about 18.4 million cords. These FAO estimates may be conservative. Bromley (*6*) estimated that by 1968 pulpwood production in the South alone would have to increase by 10.5 million cords over the 1964 level. There are also good prospects for increased exports, particularly to northwestern Europe. Thus, the pulp and paper industry in the United States can be expected to grow substantially in the years ahead. Even with improvements in forest management and technology, some areas, particularly in the South, will suffer from inadequate pulpwood production.

As a result of local wood shortages and the prospects for increased pulp outputs in the South, there

[1] Italic numbers in parentheses refer to Literature Cited, p. 36.

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FIGURE 1.—Kenaf plants near the end of the growing season. Note the lack of branching of the approximately 12-foot plants and the normal lower leaf abscission.

is interest in alternative pulp sources. Kenaf is a leading candidate. It is in the South that kenaf may have its first opportunity to prove its utility and feasibility as a fiber supplement or replacement for pulpwood. In 1967, several companies either arranged with State experiment stations or made their own test plantings of kenaf. Some test plantings were highly successful; some were not. The size of the plantings varied from about 4 acres to more than 150. Additional field trials were conducted in 1968.

While most of the industrial interest in kenaf as a pulp crop is centered in the United States, several inquiries for information and seed have been received from other countries and foreign affiliates of U.S. companies. Atchison (*3*) states that in many developing countries there are no exploitable forest resources and in others these resources are limited. Seemingly, kenaf or other similar type annual plants should hold tremendous potential for exploitation in such countries where climatic conditions are favorable.

BOTANICAL CHARACTERISTICS

Kenaf (*H. cannabinus* L.) is a member of the Malvaceae or mallow family and belongs to the section Furcaria DC., which includes 40 or more species. This section is characterized by certain distinguishing features of the calyx. Familiar kenaf relatives include okra (*H. esculentus* L.) and cotton (*Gossypium* spp.).

In dense stands, kenaf plants are largely unbranched and they may grow to a height of 8 to 20 feet (fig. 1). The bark contains the soft bast fibers that are used in some countries for cordage and spinning. The bast fiber comprises 20 to 25 percent by weight on a dry basis of the stem. A small central core containing weakly dispersed pith cells is surrounded by a thick cylinder of short, woody fibers. The fiber arrangement in the stem is shown in figure 2.

Large, showy, cream-colored flowers are borne singly in leaf axils along the stem (fig. 3). Flower-

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FIGURE 2.—Bast fibers peeled back and exposing the light-colored inner core of short, woody fibers.

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FIGURE 3.—An early-maturing kenaf plant in late bloom.

ing is indeterminate. Many kenaf varieties are photosensitive; that is, a certain period of daylight is required before flowering is initiated. The U.S.-developed varieties Everglades 71 and Everglades 41 are short-day plants and require approximately 12½ hours of light for flowering. When this day length is reached in the fall, it is too late to obtain a seed increase before a killing frost occurs except in very southerly locations.

Seed of Everglades 71 is shown in figure 4. There are approximately 18,000 seeds per pound (1,000 seeds per 25 grams).

Leaf shape and stem color vary. For example, plants of the variety Everglades 71 have deeply lobed (usually called split or divided) leaves, whereas plants of Everglades 41 have shallowly lobed (usually called entire) leaves. The first few juvenile leaves of kenaf seedlings are more or less entire in shape. Most of the varieties used in our test trials have green stems although we have several red- or purple-stemmed lines or accessions. Varietal names with letter designations refer to sources as follows:

C	Cuba.
G	Guatemala.
BG	Belle Glade, Florida.
P.I.	U.S. Department of Agriculture Plant Introduction number.

Kenaf, while highly self-fertile, should be considered as an often cross-pollinated crop. Wilson and Menzel (*70*) have described the morphology, uses, relative merits, origins, and suggested relationships of kenaf and roselle (*H. sabdariffa* L.). The cytotaxonomy of 12 species of *Hibiscus* in section Furcaria, which includes kenaf and roselle, has been described (*36*). The chromosome number of kenaf is 2n=36.

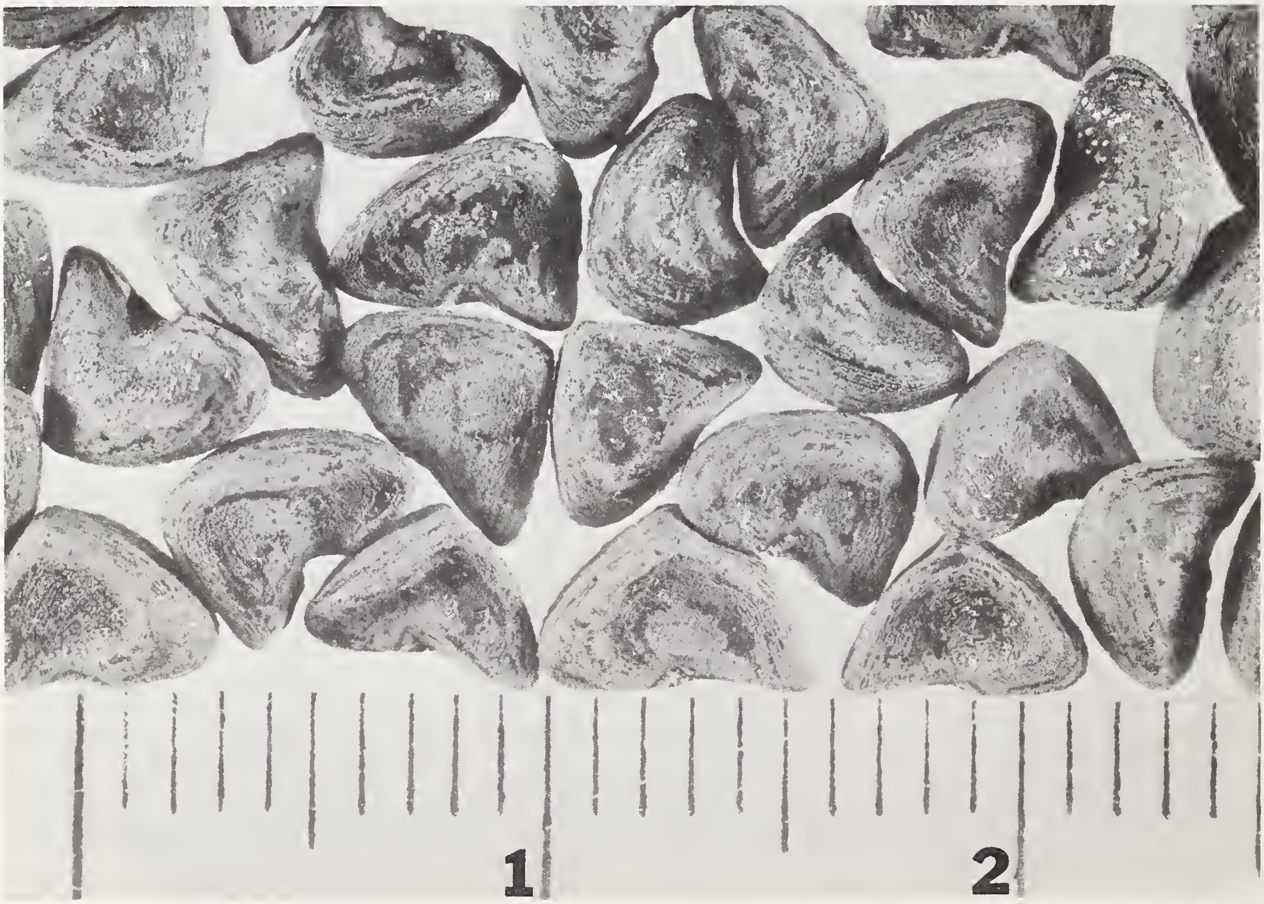

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FIGURE 4.—Seed of kenaf variety Everglades 71. (Scale is metric.)

EARLY RESEARCH EFFORT ON KENAF IN THE UNITED STATES

Cordage Fiber

In 1943–44, a program was started in southern Florida to assess the feasibility of producing, harvesting, and processing the bast (cordage) fiber of kenaf. This program resulted in the development of: (1) High-yielding varieties with resistance to the serious disease, anthracnose; (2) cultural practices for cordage fiber production; and (3) machinery to top and decorticate the crop and to wash the fiber ribbons.

The Florida research effort on kenaf for cordage was terminated in 1965 because the prospects for commercializing the crop in the United States did not appear economically promising. The research, including cooperative breeding programs in Cuba and later in Guatemala, had a beneficial impact on kenaf production in other countries. For instance, varieties that were developed by this program are widely adapted and are used in several countries. Many of the publications concerning varieties (*16, 73*), nematodes (*53, 72, 74, 75*), male sterility (*46*), insects (*22*), weed control (*44*), diseases (*45, 47, 48, 50*), genetic, cytology, and plant improvement through breeding (*34, 40, 68, 71*), and related species (*35, 36, 37, 70*) that resulted from the cordage fiber research provide valuable information applicable to kenaf as a pulp crop.

Cellulosic Fibers for Pulp

Utilization

Since the early 1930's, the U.S. Department of Agriculture has devoted some attention to possible use of nonwoody plant fibers (especially crop residues such as sugarcane bagasse and grain straw) in pulp and paper. Limited amounts of pulps from nonwood plant species are used alone and in blends with wood pulps to develop special properties in the final papers. Often premium prices are paid for these raw materials or their derived pulp. Cotton textile cuttings, thread from textile mills, salvaged rope, and burlap are typical of such raw materials.

Beginning in 1956, the Agricultural Research Service initiated a new approach to the fiber resource problem. This involved the identification of new plant species that could compete with pulpwood in furnishing satisfactory fibers for pulp and that could compete with crops of a given region in providing growers a new crop source of income. Pulp and paper producers should be able to use these fibers either alone or in conjunction with other fibers.

As the first step in identifying new sources of fibers for pulp, a botanical-analytical screening system was established (*43*). This approach was necessary to systematically evaluate samples from the large reservoir of higher plant species. Characteristics of pulpwoods and other accepted pulping materials served as a guideline in determining which properties of the nonwoody species should be measured. The resulting criteria by which the plant species were judged for their papermaking potential were as follows: (1) Botanical characteristics—based on normal habitat, form, agronomic adaptability, and size; (2) chemical composition—based on content of crude and alpha cellulose and on solubility in 1-percent NaOH solution; (3) fiber dimensions; (4) individual appraisal; and (5) yield on maceration. Numerical values were assigned to the characteristic evaluated according to their magnitude. With the least numerical value representing the best for any characteristic, the ratings were added to obtain a total point evaluation rating. A value of five was the best attainable; higher values indicated less potential. Among 387 species that were subjected to the entire screening evaluation, kenaf and sunn hemp (*Crotalaria juncea* L.) were most promising. The later decision to concentrate on kenaf rather than sunn hemp was based largely on the ability of kenaf to produce consistently higher yields with much better standability than sunn hemp. Other promising species included selected sorghums and hemp (*Cannabis sativa* L.).

Crop Production

As a result of favorable screening ratings, a modest field-testing program consisting of replicated trials with kenaf varieties, sunn hemp, and hemp was started by the Cotton and Cordage Fibers Research Branch of the Crops Research Division in 1957. This early work was in cooperation with several State experiment stations.

In general, kenaf yields obtained from these early preliminary test plantings were not high (tables 1 and 2), but optimum cultural practices

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TABLE 1.—*Dry-matter yields of 4 kenaf varieties at 11 locations in the United States, 1957–61* [1]

Location	Year	Row width	Dry-matter yield per acre			
			Everglades 71	Everglades 41	Cubano	BG 33
		Inches	*Tons*	*Tons*	*Tons*	*Tons*
Davis, Calif	1958	12		[2] 3. 17 [3] 3. 40		
Carbondale, Ill	1959	12	3. 31	3. 33		1. 68
Urbana, Ill	1957	12		[4] 2. 05		
Do	1958	12		3. 17	3. 29	
Do	1959	12	2. 72	2. 37		1. 23
Lafayette, Ind	1958	30		3. 86	4. 23	
Do	1959	12	2. 94	2. 50		1. 55
Britton, Mich	1958	12		2. 17		
Columbia, Mo	1958	12		3. 66	3. 92	
Do	1959	12	1. 66	1. 20		
Do	1960	12	[5] 2. 13			
Do	1961	30	[6] 9. 66			
Portageville, Mo	1960		[5] 1. 67			
Lincoln, Nebr	1958	12	3. 42	4. 74	4. 13	
Do	1959	12	2. 21	2. 54		1. 32
Columbia, S.C	1961		(7)			
Florence, S.C	1959		8. 65			
Do	1961	12	[8] 2. 59			
Pontiac, S.C	1959		6. 25			

[1] Data provided by the Univ. of California, Davis; D. R. Browning, Univ. of Illinois, Carbondale; C. H. Farnham, Univ. of Illinois, Urbana; H. H. Kramer, Purdue Univ., Lafayette, Indiana; Michigan State Univ., Britton; J. M. Pohlman, Univ. of Missouri, Columbia; N. A. Brown and L. E. Cavanah, Univ. of Missouri, Portageville; J. H. Williams, Univ. of Nebraska, Lincoln; and L. A. Benedict, Cotton and Cordage Fibers Research Branch, Crops Research Division, ARS, Beltsville, Md.

[2] Mean yield of stems only of Everglades 41 and Cubano, harvested on October 13.

[3] Mean yield of Everglades 41 and BG 52–7, harvested on December 5.

[4] Mean yield of Everglades 41 and Cubano. [5] Mean yield of Everglades 71 and Everglades 41.

[6] Air-dry basis. [7] Failure because of severe nematode damage, plants about 2 feet tall.

[8] Yields reduced because of nematode damage.

were not known either. In 1958, kenaf yields exceeded 4 tons per acre at Lafayette, Ind., and Lincoln, Nebr. The data indicated that further testing was needed, especially at additional sites in the southern part of the Midwest. Kenaf yielded better and was more competitive with weeds in the more southern locations. Yields in 1959 were lower than those in 1958. In the Midwest, yields appeared to be highly dependent upon climatic factors, especially temperature and soil moisture. Some yields were excellent in North Carolina in 1960 and 1961 (table 2). Much of the field research on kenaf was eventually shifted to the Southeast where the crop is well adapted. Responsibility for agronomic research on kenaf as a pulp source within the Crops Research Division was assigned to the New Crops Research Branch in 1960. Concurrent with increased emphasis on adaptation and cultural aspects, more attention was given to pulping characteristics and processing procedures. Varieties developed by the cordage fiber program have

TABLE 2.—*Dry-matter yields of 2 kenaf varieties at 5 North Carolina locations, 1960 and 1961*

Location	Year	Row width	Dry-matter yield per acre	
			Everglades 71	Everglades 41
		Inches	*Tons*	*Tons*
Clayton	1960	12	6. 11	5. 67
Plymouth	1960	12	3. 62	7. 54
Plymouth	1961	24	5. 85	6. 13
Rocky Mount	1961	12	6. 26	5. 99
Do	1961	24	4. 22	5. 10
Salisbury	1961	24	5. 66	3. 92
Willard	1960		[1] 4. 90	

[1] Mean yield for 5 row widths.

been used almost exclusively in cultural studies. Since 1965, essentially all of the research on annual pulp sources have been confined to kenaf because of its superior and consistent yielding ability and its desirable pulping characteristics.

CULTURE OF KENAF

Adaptation and Predicted Stem Yield

The Southeast with its warm temperatures and abundant moisture is particularly favorable for kenaf production. Kenaf grows well at low elevations in Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and eastern Texas. Some yields have been high in Indiana, Iowa, Kansas, Maryland, and Nebraska, but are not consistent there. The development of varieties that are not very sensitive to cool temperatures would likely broaden the area of adaptability. Kenaf responds to abundant soil moisture, but is not productive on poorly drained soils and will not tolerate standing water for very long periods, especially in its seedling stage.

Stem yields of kenaf planted in different climatic areas of the United States ranged from 2½ tons per acre in field trials at Rosemount, Minn., to 15 tons per acre at College Station, Tex. (*63*). Yields were highest in those regions with highest temperatures, longest growing season, and nonlimiting soil moisture.

To predict yields for different areas of the United States, the general effect of temperature on yield was studied at the U.S. Plant Introduction Station, Glenn Dale, Md. The study was in two steps. In the first step, the rate at which new leaves were produced at the top of the main stem was observed 2 to 5 times each week as a means of showing the plant's response to temperature (fig. 5). Higgins, Haun, and Koch (*24*) have reported methods of observing leaf development. The leaf-development approach was selected because yield determinations at frequent intervals would be impractical. In the second step, records were made at harvesttime of the stem dry weight and the number of leaves that formed on the main stem. Plants were harvested at different times to show variations in yield with number of leaves formed.

Leaf-development responses to temperature during the growing season showed that new leaves were produced at an average rate of from 0.2 of a leaf per day in early May and mid-October to somewhat more than 0.6 in midsummer. On very hot days one whole leaf developed in a single day, but growth was very slight when temperatures were below 50° F.

A summation of the average daily leaf development during the frost-free period showed that 75 leaves can be expected to develop in an average growing season at Glenn Dale, Md. A comparison of this leaf development with stem yield reveals that a stem yield of 6.8 tons per acre can be expected. In a similar manner, average expected leaf development and stem yields for several areas of the United States were estimated from temperature data for the specific areas. Through the use of average expected temperature data, kenaf yields were predicted for different areas of the United States. Those yields computed for the area east of the Rockies are shown in figure 6.

Dry-matter yields may be more than 20 tons per acre in southern Florida, in Texas south of Corpus Christi, and in the area of Arizona and California south of Death Valley. Yields of at least 10 to 12.5 tons per acre are possible as far north as eastern North Carolina; in most of Alabama, Arkansas, Georgia, Mississippi, Oklahoma, and South Carolina; in practically all of Texas; in the lower elevations of the Southwest; and in most of the California interior lands. In the far northern areas and in the mountainous regions

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FIGURE 5.—Determining the leaf-development stage of a kenaf plant.

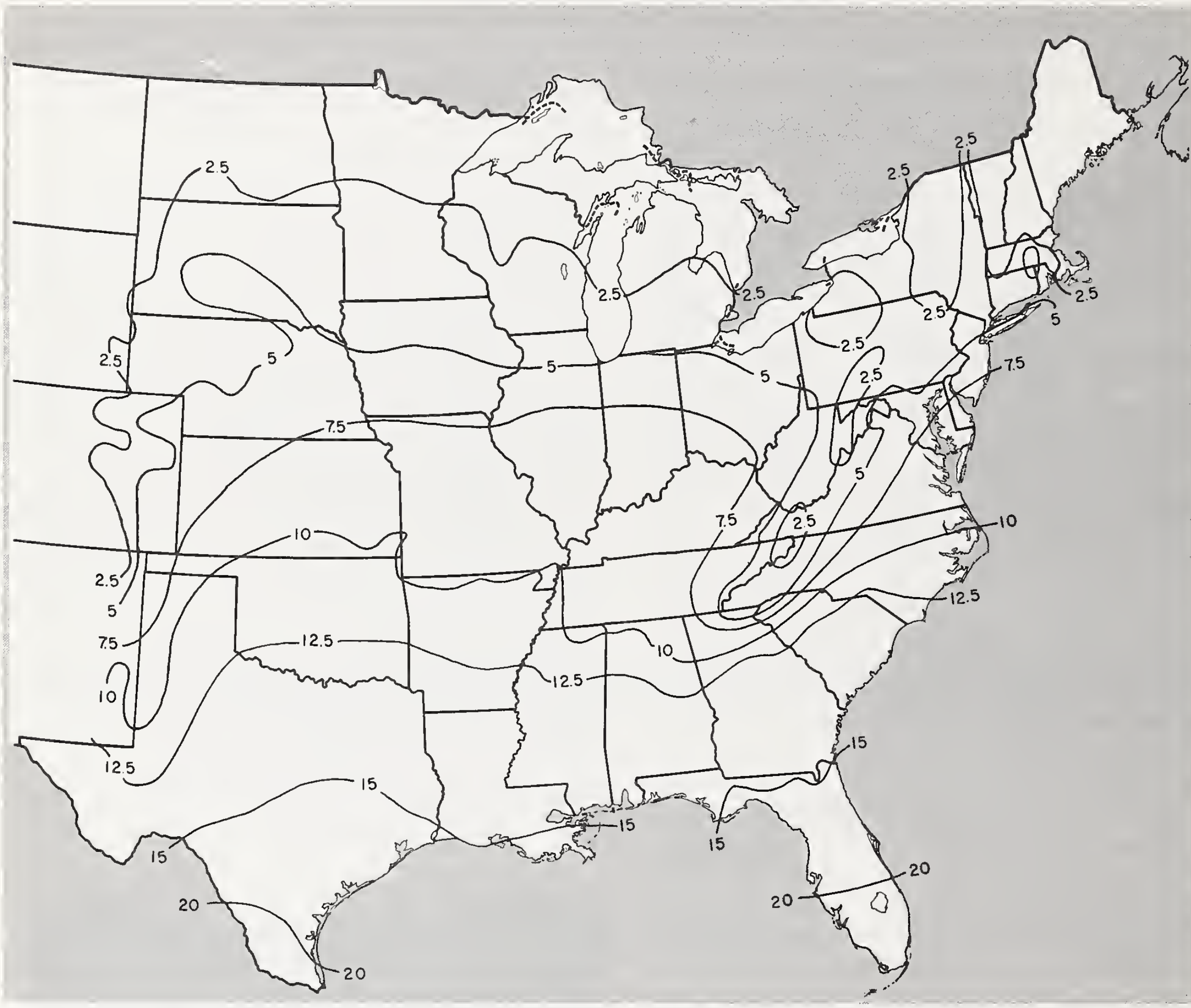

FIGURE 6.—Predicted dry-matter yields in tons per acre of kenaf for the United States east of the Rocky Mountains. Predictions are based on sufficient soil moisture and fertilizer and good cultural practices.

yields will be less than 2½ tons per acre but may be from 2½ to 5 tons in eastern Washington, along the Snake River in Oregon and Idaho, and along Lake Champlain in eastern New York.

A comparison of predicted and actual yields for a number of widely scattered plantings is given in table 3. In many instances, the actual yields were very close to the predicted yields.

We stress that predicted kenaf yields are for sufficient soil moisture and fertilizer and good cultural practices. Research now underway will show the effect of soil moisture on yields and the expected yields for different areas without irrigation. Further work may show higher potential yields than were estimated here when soil moisture, fertility, and physical conditions have been studied adequately.

Planting Dates

Planting date is an important yield factor. Late planting followed by dryness contributes to low yields because the roots of young plants do not develop sufficiently to use the limited supply of moisture. On the other hand, early planting may result in slow emergence and slow early growth if cool, moist conditions prevail. The seriousness of delayed planting will vary from year to year as some of the subsequent data will show. The

TABLE 3.—*Predicted and actual kenaf stem yields at 11 locations in the United States, 1961–67*

Location	Planting date	Stem yield per acre	
		Predicted	Actual
		Tons	*Tons*
Gainesville, Fla	Apr. 27, 1967	12. 6	9. 9
Experiment, Ga	May 2, 1967	7. 9	7. 5
Lafayette, Ind	May 4, 1964	5. 9	10. 9
Ames, Iowa	June 2, 1962	4. 5	[1] 3. 0
Do	June 1, 1964	4. 6	[2] 6. 2
Manhattan, Kans	Apr. 25, 1962	9. 0	7. 0
Do	May 17, 1963	9. 6	10. 2
Glenn Dale, Md	June 15, 1961	5. 9	5. 6
Do	June 23, 1961	5. 5	6. 5
Do	Apr. 16, 1962	7. 2	8. 4
Do	May 4, 1963	6. 4	6. 5
Do	May 16, 1966	6. 1	6. 8
Do	May 5, 1967	5. 8	5. 6
Rosemount, Minn	June 1, 1962	2. 8	2. 8
Do	June 4, 1963	4. 6	4. 9
Lincoln, Nebr	June 3, 1963	7. 9	8. 5
Plymouth, N.C	June 1, 1964	9. 3	8. 3
Clemson, S.C	May 16, 1963	8. 6	8. 7
Do	May 10, 1966	8. 2	6. 9
College Station, Tex	May 1, 1962	15. 6	15. 2
Do	May 2, 1966	12. 2	[1] 7. 2

[1] Moisture stress conditions.
[2] High rate of nitrogen applied.

best rule to follow is to use good-quality seed and plant when conditions are favorable after danger of a killing frost is over. Planting at about the same time as soybeans or cotton is suggested. Yields will be reduced more often as a result of late planting than of early planting. Approximate planting dates for nine locations are:

Location:	*Planting date* [1]
Gainesville, Fla	Apr. 5–20.
Baton Rouge, La	Apr. 20–May 5.
College Station, Tex	Apr. 20–May 5.
Savannah, Ga	Apr. 25–May 5.
Experiment, Ga	Apr. 25–May 10.
Manhattan, Kans	Apr. 25–May 10.
Clemson, S.C	May 1–10.
Glenn Dale, Md	May 1–12.
Plymouth, N.C	May 5–20.

[1] Dates are considered average but will vary somewhat from year to year because of local conditions.

In studies with 38-inch rows and four replications at Experiment, Ga., yields of Everglades 71 decreased with late planting in 1967 and 1968 (table 4). Overall yields in 1968 were probably low because of extremely dry weather, but some yield reduction may have been caused by heavy intrarow density.

TABLE 4.—*Effects of planting date on kenaf yields at Experiment, Ga., 1967 and 1968*

Planting date in 1967	Dry-matter yield per acre [1]	Planting date in 1968	Dry-matter yield per acre [1]
	Tons		*Tons*
May 2	7.5 a	Apr. 19	3.2 a
May 19	6.6 a	May 6	2.6 b
June 8	4.8 b	May 27	1.5 c
June 26	2.3 c	June 14	0.7 d

[1] Means within the same column and with a letter in common are not significantly different at the 5-percent level according to Duncan's Multiple Range test.

At Manhattan, Kans., low yields were generally associated with late planting even when the crop was irrigated (table 5). In 1963 yields were better from May 17 plantings than from May 3 plantings, but in most years planting before May 17 would be preferred.

TABLE 5.—*Effects of planting date and irrigation on kenaf yields at Manhattan, Kans., 1961–64*

Year and variety	Planting date	Irrigated [1]	Dry-matter yield per acre
1961:			*Tons*
Everglades 71	May 27	+	6. 45
Do	June 16	+	3. 99
1962:			
Everglades 71	Apr. 25	+	6. 95
Do	May 11	+	5. 15
1963:			
Everglades 71	May 3	+	7. 09
Do	May 17	+	8. 75
Everglades 41	May 3	+	10. 56
Do	May 17	+	11. 51
1964:			
Everglades 71	May 13	+	4. 9
Do	May 13	—	3. 3
Do	June 8	+	4. 5
Do	June 8	—	2. 3
Everglades 41	May 13	+	4. 4
Do	May 13	—	2. 8
Do	June 8	+	3. 0
Do	June 8	—	2. 2

[1] + indicates irrigation used; — indicates no irrigation.

Planting Methods and Rates

Most of the results included in this report are from experimental plots where small hand-pushed planters are commonly used. These planters are designed to give fairly uniform depth control and are easily calibrated to give the desired planting

rate. For large-scale planting in narrow rows, grain drills set to give shallow (½- to 1-inch) placement and with appropriate outlets plugged to give the desired row width have been very satisfactory. The drills should be adjusted to give the proper planting rate, and depth of planting should be carefully controlled. For wide rows, regular commercially available corn and soybean planters with sorghum or small soybean plates are satisfactory. The row equipment designed for 20- and 30-inch rows, which is becoming readily available, should be particularly well suited for kenaf because the narrower rows (especially 20-inch rows) will generally contribute to high yield but still permit cultivation if necessary. At the Texas Agricultural Experiment Station, a tool-bar planter that permits easy adjustment to different row widths has proved very useful in large-scale plantings. In addition to its row width versatility, its depth control is good. For areas with high water tables such as the flatwoods soils in northern Florida, planting on beds may be desirable because kenaf in the seedling stage will not tolerate much standing water.

Seeding rates will vary, depending mainly on location, row width, and the germination percentage of the seed. Generally, a final plant population of approximately 75,000 to 100,000 plants per acre is desirable. Assuming a germination of 80 percent or better and 18,000 seeds per pound, a realistic seeding rate is 6 to 8 pounds per acre. A rate of 8 to 12 pounds or more for narrow rows may be preferred in northern locations. Plants in stands that are too dense tend to be short, spindly, and prone to lodging (fig. 7). For more information on seeding rates, see the section on Row Width and Plant Population, page 15.

To increase the chances of obtaining uniform, fast-emerging stands, follow the prescription below:

(1) Use high-quality (germination 80 percent or better) seed of a recommended variety.
(2) Prepare a firm, smooth seedbed and plant after danger of killing frost is over and when there is ample soil moisture.
(3) Use a planter that will drop the seed uniformly at the recommended rate (6 to 8 pounds per acre) and will place the seed at a uniform depth of ½ to 1 inch.

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FIGURE 7.—An excessively dense stand of kenaf in Georgia in 1967.

Fertility Requirements

FLORIDA.—A fertility test involving different levels of nitrogen, phosphorus, and potassium and the application of different minor elements was planted to Everglades 71 and G-4 on April 14, 1966. A 15-inch rain in May flooded the kenaf plants, and they did not recover from the damage. An extra application of nitrogen after the flood did not help. The best yield for G-4 was just under 6 tons per acre.

Most of the kenaf trials at Gainesville have been conducted on a Leon fine sand (flatwoods soil). This soil is relatively infertile with a high water table. Planting has been on beds with 38-inch centers. Heavy fertilizer application is necessary for high yields on this soil. The usual practice has

been to fertilize with 500 to 600 pounds per acre of 8–3.5–6.6 or 10–4.4–8.3 fertilizer before bedding and to sidedress the crop with 80 to 120 pounds of nitrogen per acre 4 to 6 weeks after planting (*26*). In a pot experiment, kenaf plants (Everglades 71) grown for 68 days in a Leon fine sand responded significantly to nitrogen and potassium (phosphorus held constant) individually or in combination (*25*).

Damage from nematodes has largely precluded fertility trials on other soil types in Florida. Experimental trials for determining fertilizer response, pH effects, and other cultural requirements on different soil types are needed in Florida.

Georgia.—A split-plot experiment with four replications was conducted in 1966 and 1967 to study the influence of lime, nitrogen, phosphorus, and potassium applications on kenaf production. The soil (Cecil sandy loam) initially tested pH 5.6 with 15 pounds phosphorus and 140 pounds potassium per acre. Seed of Everglades 71 was planted on June 21, 1966, and May 26, 1967, and harvested on January 6, 1967, and November 24, 1967, respectively.

Yields did not differ significantly in either 1966 or 1967 (table 6). There was a nonsignificant trend for a yield increase from nitrogen up to 100 pounds per acre. In 1967 plants in plots that received no nitrogen were lighter in color and could be distinguished visually. Inherent soil fertility and unaccounted for plot variation probably were responsible for the lack of response to fertilizer applications. In 1967 there was a significant interaction between lime and fertilizer treatments (not shown in table 6). Lime suppressed yields at the zero and the 50-pound phosphorus levels, and increased yields at the 25-pound level. This interaction should be tested in future fertility trials.

A response to nitrogen would have been expected. In comparing the response of kenaf and other nonlegumes, including sorghum, on similar soils, the lack of response to phosphorus and potassium would be expected. Sorghum generally would have responded to nitrogen. These data indicate that kenaf either is not a heavy feeder on soil nutrients or is an efficient feeder.

Kansas.—Response to nitrogen in 1963 tests at Manhattan with three replications and two varieties was not clear-cut (table 7). In a May 3 planting, the yield from the 50-pound rate was significantly higher than that from the zero rate, but the yield from the 100-pound rate did not differ significantly from that from the zero or 50-pound rate. When planting was delayed until May 17, yields of both varieties increased at the 50- and 100-pound nitrogen rates, but not at the zero rate. The yield from plots receiving the equivalent of 100 pounds of nitrogen per acre was significantly better than that from the zero rate but not from the 50-pound rate. These tests were conducted on a Sarpy fine sandy loam. Based on the results from these tests, a nitrogen rate of 50 to 100 pounds per acre is suggested.

North Carolina.—A test with four replications at Plymouth was planted to Everglades 71 kenaf on June 1, 1962. Eight levels of nitrogen were added on August 7. Nitrogen levels and resultant yields were as follows:

Table 6.—*Effects of specific applications of fertilizer and lime on kenaf yields at Experiment, Ga., 1966 and 1967* [1]

Year and fertilizer applied (nitrogen-phosphorus-potassium) (Pounds per acre)	Dry-matter yield per acre with—	
	No lime	1,000 pounds of lime per acre
	Tons	*Tons*
1966: [2]		
0-0-0	11.3	10.4
50-50-100	11.1	10.9
100-50-100	11.2	12.3
200-0-100	11.1	9.2
200-25-100	10.9	11.6
200-50-0	10.7	11.1
200-50-50	11.4	11.4
200-50-100	11.3	11.4
Mean	11.1	11.0
1967: [3]		
0-0-0	5.9	5.7
50-50-100	6.1	6.3
100-50-100	6.6	6.6
200-0-100	7.2	4.5
200-25-100	5.8	6.7
200-50-0	6.6	5.5
200-50-50	7.7	6.0
200-50-100	7.2	4.6
Mean	6.6	5.7

[1] Yields for the same year were not significantly different at the 5-percent level according to Duncan's Multiple Range test.
[2] Irrigated as needed. [3] Not irrigated.

Nitrogen level (Pounds per acre)	Kenaf dry-matter yield[1]
	Tons per acre
33.5	4.90 a
67.0	5.35 a
100.5	5.27 a
134.0	5.27 a
167.5	4.20 a
201.0	4.80 a
234.5	4.12 a
268.0	5.10 a

[1] Yield differences were not significant.

Although no response to the different levels of nitrogen occurred, there was a tendency for slight yield suppression at rates higher than 134 pounds. The planting was made on a fertile, high-organic sandy loam. The dates for planting and applying nitrogen were both late.

On June 12, 1963, a 3 x 3 x 3 factorial test with three levels of nitrogen (0, 30, and 60 pounds per acre), phosphorus (0, 13, and 26 pounds per acre), and potassium (0, 25, and 50 pounds per acre) was planted at Plymouth in 21-inch rows. Everglades 41 was used and plants were thinned to 6 per foot of row. The main effects of nitrogen and potassium were significant (table 8), but not of phosphorus. The yield from plots receiving 60 pounds of nitrogen was significantly higher than from those receiving 0 or 30 pounds. Response with potassium was the same. An earlier planting date for this test would have been preferable.

Table 7.—*Effects of 2 planting dates and 3 rates of nitrogen on yields of 2 kenaf varieties at Manhattan, Kans., 1963*[1]

Planting date and nitrogen applied (Pounds per acre)	Dry-matter yield per acre		Nitrogen mean
	Ever-glades 71	Ever-glades 41	
	Tons	*Tons*	*Tons per acre*
May 3:			
0	6.52	9.17	7.84 b
50	8.05	11.87	9.96 a
100	6.70	10.64	8.67 ab
Varietal mean	7.09 b	10.56 a	8.83
May 17:			
0	6.46	8.27	7.36 b
50	9.19	12.04	10.61 ab
100	10.60	14.24	12.42 a
Varietal mean	8.75 a	11.51 a	10.13

[1] Means in the same box and with a letter or letters in common are not significantly different at the 5-percent level according to Duncan's Multiple Range test. Nitrogen-variety interactions were not significant at the 5-percent level.

Table 8.—*Effects of 3 rates of potassium and 3 rates of nitrogen on kenaf yields at Plymouth, N.C., 1963*[1]

Potassium applied (Pounds per acre)	Dry-matter yield per acre with nitrogen applied at—			Potassium mean
	0 pounds per acre	30 pounds per acre	60 pounds per acre	
	Tons	*Tons*	*Tons*	*Tons per acre*
0	6.5 bcd	6.4 bcd	7.0 abc	6.6 b
25	6.2 cd	5.9 d	7.4 ab	6.5 b
50	7.2 abc	7.4 ab	7.6 a	7.4 a
Nitrogen mean	6.6 b	6.6 b	7.3 a	------

[1] Means within the same box and with a letter or letters in common are not significantly different at the 5-percent level according to Duncan's Multiple Range test.

South Carolina.—A test at Clemson with three replications and three rates of nitrogen was planted to Everglades 41 on May 16, 1966, in rows 21 inches apart and harvested on November 30. Nitrogen was sidedressed at a 200-pound per acre rate on the appropriate plots on June 15, July 5, and August 10. Yields increased as the level of nitrogen increased; but under the conditions of this experiment, yields were not significantly different (table 9). Plant height exceeded 10 feet for all treatments.

Table 9.—*Effect of 3 rates of nitrogen on kenaf yields and plant height at Clemson, S.C., 1966*

Nitrogen applied (Pounds per acre)	Dry-matter yield per acre	Plants per foot of row	Plant height
	Tons	*Number*	*Inches*
200	4.53	2.7	130
400	5.00	2.5	129
600	6.90	2.5	142

Row Width and Plant Population

The desired row width and plant population will vary from area to area. More research is needed to determine if yields can be improved through modification of these two factors. Possible varietal population interactions should be explored. Good seed and precise planting equipment are important in obtaining the desired plant population. Generally, as the crop is moved northward, higher populations (with narrower rows) are necessary to obtain good yields.

Florida.—Dry-matter yields per acre from 38-inch rows have generally been greater than those from 19-inch rows on Leon fine sand (*27*). Because of a high water table, bedding, which is easily accomplished with 38-inch rows, is usually beneficial. In 1967, ten varieties were grown in plots replicated four times with 38-inch bedded and 19-inch nonbedded rows. There was no problem of too much water.

The varieties differed in their response to the two row widths. The yield of Everglades 71 was about the same for both spacings even though the number of plants in the 38-inch rows was about one-half that in the 19-inch rows (table 10). Yields from 19-inch rows of BG 52–75, BG 58–10, C–2032, Cubano, and G–4 were considerably higher than from 38-inch rows. However, yields from 38-inch rows of Everglades 41, C–108, G–45, and P.I. 305080 were higher than from 19-inch rows. Some of the yields from varieties such as Cubano were outstanding considering the low plant population.

Since bedding is preferred in soils with high water tables, research is needed to determine if yields can be improved by placing the beds closer together (perhaps 30 inches from center to center) or by planting double rows on each bed (*28*). Also, more work with varietal response to row width and plant population seems justified. For 38-inch rows, a final population of 55,000 or more plants per acre (4 plants per linear foot of row) appears necessary to obtain high yields of most varieties. A 6-pound-per-acre seeding rate should provide an adequate stand. Plants, especially those that are small or diseased, tend to lodge late in the season. Lodging can be severe in thick stands. The correct population with uniform stands minimizes lodging. This emphasizes the importance of planting equipment that gives uniform seed droppage and depth control.

Georgia.—Everglades 71 was grown in plots with two and four plants per foot of row in rows spaced 12, 24, and 36 inches apart in 1966 and 1967 (Cecil sandy loam). Preplant fertilization consisted of 600 pounds per acre of 6–5.3–10 (nitrogen, phosphorus, and potassium) in 1966 and 10–4.4–8.3 in 1967. Planting dates were June 23, 1966, and June 7, 1967. Weeds were controlled by hand cultivation. Plots were harvested on January 6, 1967, and November 24, 1967. Since there was no significant difference in yields between two and four plants per foot of row regardless of row width, yields (table 11) represent the means for the two populations. For both years, there was an increased but insignificant yield trend with two plants as compared to four plants per foot of row. For the 2-year average, yields from plots with 12- and 24-inch rows were significantly greater than from plots with 36-inch rows. In 1966, yields from the three row widths were all significantly different, with yields decreasing as the row width increased. In 1967, yields from 12- and 36-inch rows did not differ from each other, but they were significantly lower than the yield (10.4 tons per acre) from 24-inch rows. These data indicate that for best yields in Georgia rows should be narrower than 36 inches.

Table 10.—*Effects of 2 row widths on kenaf yields at Gainesville, Fla., 1967*

Variety or introduction	38-inch bedded rows		19-inch nonbedded rows	
	Dry-matter yield per acre[1]	Plants per acre	Dry-matter yield per acre[1]	Plants per acre
	Tons	*Number*	*Tons*	*Number*
Everglades 71	9.93 a	54, 600	9.63 ab	91, 950
Everglades 41	9.96 a	64, 450	8.31 ab	109, 150
BG 52–75	[2] 7.63	12, 900	[2] 9.98	21, 500
BG 58–10	6.92 b	55, 450	10.70 a	95, 400
C–108	7.56 b	53, 300	6.60 b	86, 800
C–2032	7.92 b	55, 450	9.59 ab	99, 700
Cubano	[2] 5.22	10, 750	[2] 8.96	33, 500
G–4	6.55 b	52, 450	8.92 ab	92, 850
G–45	8.01 b	62, 300	6.72 b	98, 000
P.I. 305080	[3] 4.08	36, 100	2.96 c	66, 200

[1] Means within the same column and with a letter or letters in common are not significantly different at the 5-percent level according to Duncan's Multiple Range test.
[2] Poor stands, data not analyzed.
[3] Only 2 replications, data not analyzed.

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TABLE 11.—*Effects of 3 row widths on kenaf yields at Experiment, Ga., 1966 and 1967* [1]

Year	Dry-matter yield per acre for row width of— 12 inches	24 inches	36 inches	Mean for year
	Tons	*Tons*	*Tons*	*Tons per acre*
1966	7.8 a	7.1 b	5.6 c	6.8 a
1967	7.9 b	10.4 a	7.5 b	8.6 b
Mean for row width	7.8 a	8.8 a	6.5 b	--------

[1] Means within the same box and with a letter in common are not significantly different at the 5-percent level according to Duncan's Multiple Range test.

MARYLAND.—In a 1966 study at Glenn Dale, a population of 80,000 plants per acre resulted in the best dry-matter yields (*64*). A natural mortality or thinning occurred in each population studied, but the rate of mortality was considerably higher for the higher population levels. For most kenaf varieties, a population of about 80,000 to 100,000 plants per acre is suggested for Maryland conditions. (See table 18, p. 21.)

NEBRASKA.—Results from studies in Nebraska indicate that plant populations of 2.5 or more plants per square foot (108,900 plants per acre) may be necessary for high yields under conditions of ample moisture and fertility (*67*). In irrigated experiments, the highest yields were from narrow rows. In a 1962 nonirrigated test, yields from 7-, 14-, 21-, and 28-inch rows with populations ranging from 0.8 to 2.0 plants per square foot (34,800 to 87,100 plants per acre) were not significantly different. Good moisture conditions prevailed during the growing season.

NORTH CAROLINA.—Row width and plant density studies have been conducted for several years at Plymouth (*21*). Results in 1966 show that: (1) Largest yields resulted from 14-inch rows with two plants per foot of row (74,700 plants per acre); (2) smallest yields resulted from 7-inch rows and the wider 28- and 35-inch rows; (3) high plant density was necessary for high yields in wide rows; and (4) the final stand in 7-inch rows was usually about the same, regardless of the seeding rate. Plant heights and basal stem diameters increased as row width increased.

The population for 14-inch rows with two plants per foot of row would be about 74,700 plants per acre. This population should be obtained with a seeding rate of 6 pounds per acre.

TEXAS.—Two row widths and two Everglades varieties were compared in 1960–61 studies (table 12). Although the best yields resulted from 20-inch rows, the yield differences between 20- and 40-inch rows were significant only in 1960. In both years, yield from Everglades 71 was significantly higher than from Everglades 41. Interactions of magnitude were significant both years.

TABLE 12.—*Effects of 2 row widths on yields of 2 kenaf varieties at College Station, Tex., 1960 and 1961* [1 2]

Year and variety	Dry-matter yield per acre for row width of— 20 inches	40 inches	Varietal mean
1960:	*Tons*	*Tons*	*Tons per acre*
Everglades 71	6.71 a	5.73 b	6.22 a
Everglades 41	6.58 a	4.98 c	5.78 b
Mean for row width	6.64 a	5.36 b	---------
1961:			
Everglades 71	5.69 a	4.97 ab	5.33 a
Everglades 41	4.66 b	4.39 b	4.53 b
Mean for row width	5.18 a	4.68 a	---------

[1] Planting and harvesting dates were May 1 and December 5, 1960, and May 5 and December 8, 1961. There were 4 replications in each experiment.
[2] Means within the same box and with a letter or letters in common are not significantly different at the 5-percent level according to Duncan's Multiple Range test.

In 1966, four row widths and eight varieties were included in split plot experiments with four replications and two planting dates (table 13). These experiments were not irrigated.

There was no difference between yields from 7- and 14-inch rows for the May 2 planting, but yields from 7-inch rows were significantly higher than those from 21-inch rows. There was no difference between yields from 21- and 42-inch rows. Yields of Everglades 71 were usually substantially (and significantly) higher than yields of the other varieties. Yields of Everglades 71 for the four row widths were not significantly different.

TABLE 13.—*Effects of 2 planting dates and 2 row widths on dry-matter yields of 8 kenaf varieties at College Station, Tex., 1966* [1] [2]

Planting date and variety	Dry-matter yield per acre for row width of—				Varietal mean
	7 inches	14 inches	21 inches	42 inches	
	Tons	*Tons*	*Tons*	*Tons*	*Tons per acre*
May 2:					
Everglades 71 Special [3]	6.28	5.75	5.39	4.09	5.38 bc
Everglades 41 Special [3]	5.60	5.55	5.47	5.22	5.46 bc
C–108	5.71	5.89	5.02	6.23	5.71 b
United Late	5.19	4.78	4.37	4.31	4.66 d
C–2032	5.51	4.96	5.50	5.08	5.26 bcd
G–4	4.93	5.61	4.15	5.08	4.94 d
Everglades 41	5.42	5.64	5.47	4.45	5.24 bcd
Everglades 71	7.19	6.52	7.21	6.76	6.92 a
Mean for row width	5.73 a	5.59 ab	5.32 bc	5.15 c	
June 1:					
Everglades 71 Special [3]	3.31	5.10	4.48	3.36	4.06 bc
Everglades 41 Special [3]	4.47	3.65	4.04	4.93	4.27 b
C–108	3.24	3.53	3.69	4.58	3.76 cd
United Late	3.08	4.23	2.97	2.85	3.28 e
C–2032	3.56	3.51	3.80	3.71	3.64 d
G–4	3.67	3.61	3.71	3.09	3.52 de
Everglades 41	4.47	5.09	4.88	4.49	4.80 a
Everglades 71	4.31	4.69	4.05	2.85	3.98 bc
Mean for row width	3.80 bc	4.18 a	3.95 b	3.73 c	

[1] Harvesting date was December 12. There were 4 replications in each experiment.
[2] Means within the same box and with a letter or letters in common are not significantly different at the 5-percent level according to Duncan's Multiple Range test.
[3] Selections from Everglades 71 and Everglades 41.

Yields from the June 1 planting were considerably less than those from the earlier planting on May 2. The best mean yield of 4.18 tons per acre from 14-inch rows was significantly greater than mean yields from other row widths. The mean yield from 21-inch rows was significantly greater than that from 42-inch rows. In this planting, yields of Everglades 41 were significantly higher than those of the other varieties.

Interactions from both of the 1966 plantings were significant but are not shown in table 13. For most of the varieties, yields tended to decrease as row width beyond 14 inches increased.

The data in table 13 indicate that planting in rows spaced 7 or 14 inches apart will result in the largest yield. However, in view of weed control, seeding rate, and harvesting methods, rows spaced 20 to 30 inches apart are recommended for the College Station, Tex., area. More study of row widths may be desirable for different soil types and areas in Texas.

Weed Control

In the Southeast kenaf plants, because of their quick emergence and rapid growth, can compete successfully with weeds. However, as we attempt to grow kenaf in different areas with varying climatic conditions, soil types, and earlier planting dates, reliable measures of weed control need to be found. No weed control is needed in drilled, narrow-row plantings in southern Florida or in wide-row plantings on flatwoods soils in northern Florida. On the other hand, weed problems may be serious on high-organic soils in northern Florida and southern Georgia. Chemical or cultural weed control is necessary in northern locations because kenaf cannot compete successfully with weeds in these areas.

Ultimately, a preplant or preemergence application of an effective herbicide will help to control weeds until kenaf plants are well established. However, since no herbicides have been registered

for use on kenaf, the crop should be grown in rows wide enough to permit tractor cultivation. In most areas this row width should be 30 inches or less.

There is limited literature pertaining to herbicidal usage as preplanting or preemergence treatments for weed control in kenaf. In Nebraska studies, trifluralin (*alpha*, *alpha*, *alpha*-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine) was the most selective of the herbicides tested (*7*). In 1964, a 2-pound-per-acre rate (2.2 kg./ha.) of trifluralin significantly depressed yields as compared with a hand-weeded check plot, but in 1965–66 yields from plots receiving 1 and 2 pounds per acre (1.1 and 2.2 kg./ha.) were not different from those of check plots. The rate of 1 pound per acre was as effective for weed control as 2 pounds per acre. Amiben (3-amino-2,5-dichlorobenzoic acid) at 3 pounds per acre (3.4 kg./ha.) controlled the weeds but killed 60 percent of the kenaf plants.

In a 1965 trial at Experiment, Ga., trifluralin at ¾ pound per acre controlled all weeds; however, in Illinois and Indiana in 1967, weed control was inadequate with this chemical, mainly because of its ineffectiveness in controlling certain broadleaf weed species. In Maryland in 1967 and 1968, trifluralin was effective in controlling all early season weeds except nutsedge (*Cyperus esculentus* L.). At Clemson, S.C., in 1966, 1967, and 1968, trifluralin at 1 pound per acre controlled weeds consistently and effectively.

In a preliminary herbicide evaluation study at Savannah, Ga., weed control was best with the use of vernolate (*S*-propyldipropylthiocarbamate) at 2 pounds per acre, EPTC (*S*-ethyl dipropylthiocarbamate) at 1.5 pounds per acre, and amiben ester at 6 pounds per acre (table 14). Kenaf tolerance was too low for amiben ester and marginal for vernolate and EPTC. It may be possible to improve the tolerance through manipulation of the herbicide placement. Tolerance for some of the herbicides was good, but they provided inadequate weed control. Weeds present included nutsedge, lambsquarters, Florida purslane, and crabgrass.

Orsenigo (*44*) has evaluated kenaf tolerance to herbicides applied preplant, preemergence, and postemergence in southern Florida. Chemicals rated as superior and for which additional research on rates and methods of application is needed include diphenamid (*N*,*N*-dimethyl-2,2-diphenylacetamide), dichlorobenil (2,6-dichlorobenzonitrile), 2,4-D [(2,4-dichlorophenoxy)acetic acid] applied preemergence only, EPTC, PCP (pentachlorophenol), and monuron [3-(*p*-chlorophenyl)-1,1-dimethylurea]. A combination of CDAA (*N*, *N*-diallyl-2-chloroacetamide) and CDEC (2-chlorallyl diethyldithiocarbamate) controlled the weeds effectively on organic soil; however, slight temporary injury has followed the use of the chemicals, especially with shallow-planted seed and high soil moisture. In addition, kenaf exhibited excellent tolerance to propanil (3′,4′-dichloropropionanilide) applied as a preemergence treatment.

TABLE 14.—*Preliminary evaluations of herbicides with kenaf in Georgia, 1967* [1]

Herbicide	Rate of active ingredient per acre	Tolerance	Weed control
	Pounds	*Percent*	*Percent*
Amiben ester	6.0	51	86
Amitrole and simazine [2]	1.5	95	58
DCPA [3]	10.0	88	57
EPTC	1.5	66	87
Norea [4]	0.5	81	44
Trifluralin	1.5	79	80
Vernolate	2.0	65	93

[1] Data provided by H. T. DeRigo, formerly Crops Research Division, and W. O. Hawley, Crops Research Division, ARS. 17 herbicides, some with two or three rates were evaluated in this study. Those listed in the table, except amiben, seem to merit additional consideration.

[2] Mixture of 15 percent amitrole (3-amino-*s*-triazole) and 45 percent simazine [2-chloro-4,6-bis(ethylamino)-*s*-triazine].

[3] DCPA (dimethyl tetrachloroterephthalate).

[4] Norea [3-(hexahydro-4,7-methanoindan-5-yl)-1,1-dimethylurea].

The performance of herbicides is affected by soil and climatic factors. Also, weed control programs must consider specific weed infestation problems.

Research on weed control is needed to develop effective control measures for different soils, weed populations, and areas. The foregoing discussion provides a guide to chemicals that should be evaluated more intensively. *No herbicides have been registered by the Department of Agriculture for use on kenaf.*

Varieties and Varietal Yield Tests

The varieties best known and most extensively used in field tests by U.S. workers are Everglades 71 and Everglades 41. These are from lines that were selected from the El Salvador accession (P.I. 207883) and inbred (*73*). Both varieties are resistant to anthracnose caused by *Colletotrichum hibisci* Poll. They are short-day plants that flower in early to mid-October in southern Florida at latitude 27° N. when planted from about March 1 to August 15. Other productive varieties have evolved from programs in Cuba, Guatemala, and South Africa. C–2032 and G–4 are considered to be insensitive to day length; that is, there is no strict day-length requirement for floral initiation. Generally, the best yields in Southeastern United States have resulted from the use of Everglades 71. It is recommended as the first choice of the available varietes. Some varieties and introductions have not been sufficiently tested to determine their performance.

Varietal Tests in Florida.—In 1967 varietal tests with 4 replications and 10 entries were set up at Glenn Dale, Md., Clemson, S.C., and Gainesville, Fla. Cultural details of these plantings are presented in table 15.

Results from the Gainesville, Fla., test are given in table 10, page 15. Yields of Everglades 71 and Everglades 41 were signficantly higher than those of other varieties in 38-inch bedded rows. Except for P.I. 305080, yields among the varieties from 19-inch nonbedded rows were more nearly the same than yields from 38-inch rows. The top yield of 10.70 tons per acre from BG 58–10 from 19-inch rows was not signficantly different from the yields of Everglades 71, Everglades 41, C–2032, and G–4. Considering the low plant population, the yields of BG 52–75 and Cubano were outstanding for both row widths but particularly for the 19-inch row width. The yields of the early maturing line P.I. 305080 were quite low.

In 1968 a variety-fertility test with four replications was planted at Gainesville, Fla., on March 22 on bedded rows spaced 38 inches apart at a 6-pound per acre rate. Plots were fertilized at planting with 100 pounds of nitrogen, 44 pounds of phosphorus, and 83 pounds of potassium per acre. A side dressing of two nitrogen and three potassium levels was applied on May 15. In the analysis of the data, there were no significant effects from the fertilizer treatments or the fertilizer-variety interaction. Dry-matter yields of the six varieties were as follows:

Variety:	Mean dry-matter yield [1] *Tons per acre*
Everglades 71	9.16 a
Everglades 41	8.13 ab
G–4	7.53 b
G–45	7.09 bc
C–2032	6.23 cd
C–108	5.83 d

[1] Means with a letter or letters in common are not significantly different at the 5-percent level according to Duncan's Multiple Range test.

Varietal Tests in Georgia.—Varietal tests with four replications at Experiment, Ga., were planted on a Cecil sandy loam on June 16, 1964, May 2, 1967, and May 21, 1968. The row widths were 7 inches in 1964 and 38 inches in 1967 and 1968. The late planting date in 1964 and 1968 contributed to low yields. Yields for 1967 were quite good considering that row widths were 38 inches (table 16). Yields in 1968 were greatly reduced by the late planting date, low rainfall, and poor stands. Plots with Everglades 71, which is usually the best yielding variety at this location, had an estimated stand of only 18 percent.

Table 15.—*Cultural practices for a 3-location, 10-entry kenaf varietal test, 1967*

Location	Date of—		Row width	Fertilizer per acre			Soil type
	Planting	Harvesting		Nitrogen	Phosphorus	Potassium	
			Inches	*Pounds*	*Pounds*	*Pounds*	
Gainesville, Fla	Apr. 27	Nov. 17 [1]	19, 38	247	65	166	Leon fine sand.
Glenn Dale, Md	May 19	Oct. 11, 12 [1]	18	200	88	84	Collington sandy loam.
Clemson, S.C	June 13	Nov. 8 [2]	21	184	44	83	Mixed alluvial.

[1] Prefrost. [2] Postfrost.

TABLE 16.—*Dry-matter yields of 16 kenaf varieties at Experiment, Ga., 1964, 1967, and 1968*

Variety or introduction	Dry-matter yield per acre [1]		
	1964	1967	1968 [2]
	Tons	*Tons*	*Tons*
BG 52–52	4. 6 a		
Cubano	4. 3 ab		2. 1 abc
Everglades 41	3. 8 bc	8. 1 a	2. 3 abc
Everglades 71	3. 6 bc	8. 2 a	1. 4 bc
BG 52–75	3. 4 bc		2. 7 a
BG 58–10	3. 2 c		2. 1 abc
C–108		8. 1 a	3. 2 a
C–2032		5. 2 c	3. 0 a
G–4		5. 1 c	3. 1 a
G–45		6. 8 b	3. 3 a
SH/15R			2. 9 a
GR 25/63			2. 6 ab
ST/11760			2. 3 abc
P.I. 208832			2. 1 abc
P.I. 196988			1. 2 c
P.I. 318723			1. 1 c

[1] Means within the same column and with a letter or letters in common are not significantly different at the 5-percent level according to Duncan's Multiple Range test.
[2] Stands were inadequate for most varieties.

Some varieties of roselle are highly resistant to some root-knot nematodes, but the range of resistance to the various species is not known. On May 20, 1968, at Savannah, Ga., five roselle varieties and Everglades 71 (kenaf check variety) were planted in rows spaced 20 inches apart. Dry-matter yields were as follows:

Variety:	Dry-matter yield [1] *Tons per acre*
Kenaf check (Everglades 71)	5. 12
Roselle:	
THS–2	5. 76
THS–12	7. 52
THS–17	8. 31
THS–30	6. 22
THS–44	6. 89

[1] Data provided by W. O. Hawley, Crops Research Division, ARS.

The plots were small and yields were variable because of stand variation, uneven nematode infestation, and, perhaps, nitrogen deficiencies. Nevertheless, the roselle varieties did grow and yield well. They did not flower. Stems were rough with spines, but the spines were noted to be softer and less tenacious than those on kenaf. These yield results show that these and a few other selected roselle varieties should be screened for root-knot nematode resistance and the more resistant ones evaluated for yield potential in different areas of nematode infestation in the Southeast. Their seed-producing characteristics should also be assessed.

VARIETAL TEST IN KANSAS.—A varietal test with four replications at Manhattan, Kans., was planted in 12-inch rows on May 19, 1967. Plots were not irrigated. Yield differences were not significant (table 17). Under nonirrigated conditions in this area, the use of wider row widths might result in increased yield because moisture is usually a limiting factor, especially on light soils.

TABLE 17.—*Dry-matter yields and plant heights of 4 kenaf varieties at Manhattan, Kans., 1967*

Variety	Dry-matter yield per acre [1]	Plant height
	Tons	*Feet*
Everglades 71	4. 62 a	7. 2
C–108	5. 11 a	7. 4
C–2032	4. 72 a	7. 7
G–45	4. 29 a	7. 0

[1] Yield differences were not significant at the 5-percent level according to Duncan's Multiple Range test.

VARIETAL TEST IN MARYLAND.—Cultural details of the Maryland varietal test set up in 1967 are shown in table 15. The Glenn Dale, Md., planting was thinned to approximately four plants per foot of row, except varieties BG 52–75 and Cubano. In this test, the yield of whole plants and stems only of Everglades 71 exceeded those of the other varieties, but the differences were not always significant (table 18). Because of poor stands, data for the varieties BG 52–75 and Cubano were not included in the analysis. However, the yield of Cubano (approximately 3.18 tons per acre of whole plants and 2.55 for stems only) with an average stand of only one plant per foot of row justifies further consideration of the variety. The Everglades varieties were less susceptible to diseases than the other varieties. The P.I. accession was earlier maturing and more susceptible to disease (mainly gray mold caused by *Botrytis cinerea* Pers. ex Fr.). The yield and height of this accession probably would have been greater if the crop had been harvested earlier. However, its stem yield was not significantly less than that of Everglades 71, the highest yielder.

TABLE 18.—*Results of kenaf varietal test at Glenn Dale, Md., 1967* [1]

Variety or introduction	Dry-matter yield per acre		Plant height	Basal stem diameter	Rating of—		Plants per acre
	Whole plants	Stems			Disease [2]	Maturity [3]	
	Tons	*Tons*	*Inches*	*Millimeter*			*Thousands*
Everglades 71	7.18 a	6.06 a	116 a	16 ab	2	1	110
Everglades 41	6.84 ab	5.94 a	108 ab	15 b	2	1	110
BG 52–75 [4]	4.38	3.62	103	17	3	1	55
BG 58–10	5.30 c	4.59 b	95 b	15 b	5	4	96
C–108	6.31 abc	5.36 ab	106 ab	18 a	4	1	99
C–2032	5.98 abc	5.16 ab	102 ab	16 ab	5	4	96
Cubano [4]	3.18	2.55	113	22	3	2	29
G–4	6.66 ab	5.73 a	106 ab	17 ab	5	4	105
G–45	7.16 a	6.01 a	109 ab	16 ab	4	2	107
P.I. 305080	5.64 bc	5.20 ab	99 b	16 ab	6	5	93

[1] Means within the same column and with a letter or letters in common are not significantly different at the 5-percent level according to Duncan's Multiple Range test.
[2] A measure of disease incidence (primarily gray mold caused by *Botrytis cinerea* Pers. ex Fr.); rating 1 to 9 (none to dead).
[3] Rating of 1 to 5 (early bud to late flower).
[4] Not included in analysis because of poor stands.

VARIETAL TEST IN NORTH CAROLINA.—Six varieties of kenaf were planted in 21-inch rows on June 7, 1967, at Plymouth, N.C. Soil moisture was adequate during the growing season. Results are shown in table 19. Yields were low because of late planting.

TABLE 19.—*Plant height, basal stem diameter, and dry-matter yields of kenaf varieties at Plymouth, N.C., 1967*

Variety	Distance between plants in row	Plant height	Basal stem diameter	Dry-matter yield per acre [1]
	Inches	*Inches*	*Millimeters*	*Tons*
C–108	2.6	95	14	3.00 b
C–2032	2.6	89	14	2.90 b
G–4	2.2	92	16	2.96 b
G–45	3.2	88	12	3.08 b
Everglades 41	2.6	93	16	3.82 a
Everglades 71	3.8	86	13	3.81 a

[1] Means within the same column and with a letter in common are not significantly different at the 5-percent level according to Duncan's Multiple Range test.

VARIETAL TEST IN SOUTH CAROLINA.—Cultural details of the South Carolina varietal test set up in 1967 are shown in table 15. The Clemson, S.C., planting was thinned to approximately four plants per foot of row, except varieties BG 52–75 and Cubano. In this test, yields were low because of late planting and somewhat low populations (table 20). The herbicide trifluralin at 1 pound active ingredient per acre controlled weeds effectively.

TABLE 20.—*Results of kenaf varietal test at Clemson, S.C., 1967* [1]

Variety or Introduction	Air-dry yield per acre	Plant height	Plants per acre
	Tons	*Inches*	*Number*
Everglades 71	2.50	92	72,200
Everglades 41	3.24	100	87,100
BG 52–75	2.47	95	42,300
BG 58–10	2.64	102	77,200
C–108	2.75	102	64,700
C–2032	2.55	94	69,700
Cubano	1.73	102	44,800
G–4	1.87	96	74,700
G–45	2.36	94	72,200
P.I. 305080	1.82	113	69,700

[1] Because of a late planting date and poor stands of some varieties, data were not analyzed.

VARIETAL TESTS IN TEXAS.—A planting was seeded on May 24, 1967, at Beaumont, Tex., in 18-inch bedded (ridged) rows, and stands were thinned to four plants per linear foot of row (116,200 plants per acre). The planting was irrigated three times. An April 15 to May 1 planting date is suggested for this location. The yield of Everglades 71, while highest, was not significantly different from the yield of BG 58–10, Everglades 41, G–45, and C–108 (table 21).

TABLE 21.—*Dry-matter yields of 7 kenaf varieties at Beaumont, Tex., 1967* [1]

Variety [2]	Dry-matter yield per acre [3]
	Tons
C-2032	5.4 c
BG 58-10	5.8 bc
G-4	5.1 c
Everglades 71	7.0 a
Everglades 41	6.6 ab
G-45	6.4 ab
C-108	6.8 a

[1] Data provided by J. R. Wood, Texas A. & M. University, Beaumont.
[2] Varieties listed in order of maturity (earliest to latest).
[3] Means within the same column and with a letter or letters in common are not significantly different at the 1-percent level according to Duncan's Multiple Range test.

Varietal tests with four replications were conducted at College Station, Tex., in 1965 and 1966 (table 22). Yield differences for the May 1 plantings in both 1965 and 1966 were not significant. In 1966, the yield of United Late was significantly less than that of Everglades 41, Everglades 41 Special, and Everglades 71.

TABLE 22.—*Dry-matter yields of 5 kenaf varieties at College Station, Tex., 1965 and 1966*

Variety	Dry-matter yield per acre [1]		
	1965	1966	
	Planted May 1	Planted May 1	Planted May 19
	Tons	*Tons*	*Tons*
C-108	4. 51 a	5. 97 a	4. 91 ab
G-4	4. 23 a	4. 26 a	4. 41 ab
Everglades 41	4. 74 a	4. 95 a	5. 76 a
Everglades 41 Special	3. 41 a	4. 15 a	5. 54 a
Everglades 71	4. 60 a	4. 85 a	5. 73 a
Everglades 71 Special	4. 91 a	5. 92 a	4. 86 ab
United Late	3. 27 a	4. 20 a	3. 75 b

[1] Means within the same column and with a letter or letters in common are not significantly different at the 5-percent level according to Duncan's Multiple Range test.

SOUTHERN REGIONAL VARIETAL TESTS.—In these tests, Everglades 71 and Everglades 41 were compared in 1963 and 1964 at several locations (table 23). Results indicate poor yield potential under dryland conditions at Stillwater, Okla.

TABLE 23.—*Effects of row width and planting date on yields of 2 kenaf varieties in Southern Regional varietal tests, 1963 and 1964*

Location	Row width	Planting date	Dry-matter yield per acre	
			Everglades 71	Everglades 41
	Inches		*Tons*	*Tons*
Gainesville, Fla	38	May 6, 1963	5. 33	4. 54
Do	38	May 20, 1964	7. 60	7. 20
Experiment, Ga	36	May 8, 1963	4. 29	3. 73
Do	36	May 13, 1964	6. 84	5. 95
Baton Rouge, La.[1]	48	May 20, 1964	[2] 7. 49	[2] 8. 79
Plymouth, N.C	21	June 12, 1963	5. 10	4. 20
Rocky Mount, N.C.	14	May 6, 1964	5. 18	4. 27
Willard, N.C	21	May 7, 1963	6. 60	6. 60
Stillwater, Okla.[3]	20	May 17, 1963	3. 63	3. 11
Do	40	May 17, 1963	4. 01	4. 06
Do	40	May 20, 1964	4. 12	3. 13
Clemson, S.C	21	May 10, 1963	8. 70	7. 84
College Station, Tex.	40	May 1, 1963	3. 22	4. 41
Do	40	May 1, 1964	6. 00	6. 01

[1] Data provided by J. C. Miller, Louisiana State Univ., Baton Rouge.
[2] Air-dry yields.
[3] Data provided by R. M. Oswalt and R. S. Matlock, Oklahoma State Univ., Stillwater.

Harvesting Date

There is limited information available concerning harvesting dates for kenaf. The usual practice with experimental plots has been to harvest sometime after a killing frost. Where field drying conditions are favorable, the standing crop may be left a month or longer for drying before harvest. Mold and other organisms appear on stalks and severe lodging may occur within 2 or 3 weeks after a killing frost in northern Florida (*28*). Thus, the plots should be harvested either before or immediately after frost. In a 1966 Maryland study, dry-matter yields were highest at about the time of frost (*64*). Later harvests, especially in early December and January, resulted in significant yield decreases.

The timing of harvests is unimportant for pulp preparation if the crop is harvested after about 120 days from time of planting (*13*). Therefore, the timing of harvests becomes largely a matter of yield economics. Of course, storage methods may

be affected. In areas with long growing seasons, maximum yields may actually be obtained sometime before the first killing frost. A crop of tall kenaf plants with several lodged plants is shown in figure 8. Within a few days, these lodged plants will not be harvestable. Whether additional growth before frost will compensate for or surpass the yield lost from the lodged plants is questionable. Note that most of the leaves have dropped even though frost had not occurred. It may be desirable, if yield reductions are not too great, to begin harvesting several weeks before frost and continue for several weeks afterwards. Experiments in several areas are needed to study the effects of different harvest dates on yields.

BN–35372

FIGURE 8.—Late-season lodging of tall kenaf plants in 40-inch rows.

Seed Germination, Treatment, and Storage

Seedlings from high-quality kenaf seed will emerge in the field within 3 to 5 days when planted at the proper depth and under favorable soil moisture and temperature conditions. Rapid emergence is very important for obtaining competitive, uniform stands. Germination tests should be run before planting, and seed that germinates poorly should not be used. The official method for testing laboratory germination of kenaf seed is: Substrata—paper towel, used either folded or rolled in horizontal or vertical position or between blotters; 20 and 30° C. alternating temperatures (16 hours at 20° and 8 hours at 30°); first count at 4 days; and final count at 8 days (*2*). Seed purchasers should insist that the germination be 80 percent or better.

Seed treatment with thiram [bis(dimethylthiocarbamoyl)disulfide] at 2 ounces per 100 pounds of seed materially reduced damage from anthracnose during the seedling stage in susceptible kenaf varieties (*50*). In Texas, greenhouse and field experiments indicated that captan (*N*-[(trichloromethyl)thio]-4-cyclohexane-1,2-dicarboximide), ceresan (ethyl mercury phosphate), a mixture of 60 percent thiram and 15 percent dieldrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-*endo-exo*-5,8-dimethanonaphthalene), and semesan [2-chloro-4-(hydroxymercuri)phenol] could be used as a protectant on kenaf seed (*65*). *None of these or any other chemicals for seed treatment have been registered for use on kenaf seed.* More research on chemical effectiveness is required before U.S. Department of Agriculture registration can be obtained.

Kenaf seed will deteriorate rapidly when stored under warm, humid conditions but will retain its viability over long periods if properly stored. Seed conditioned to 8-percent moisture retained full viability for 5½ years when stored at —10°, 0°, and 10° C. (*54*). At 12-percent seed moisture, viability remained essentially unchanged for 5½ years at —10° and 0°, but there was a significant loss in viability in 4 to 4½ years when stored at 10°. Seed stored under normal atmospheric conditions in Cuba deteriorated markedly within 6 months, but seed from the same lot retained full viability for

16 months when stored in a dehumidified room. At the U.S. Department of Agriculture Plant Introduction Station, Glenn Dale, Md., seed has been stored for 2 to 3 years at 0.6° and 30 to 35 percent relative humidity without appreciable loss in viability. Growers are urged to store any excess seed under dry, cool conditions to minimize loss of seed viability.

Disease, Insect, and Nematode Pests

The occurrence of serious diseases has been infrequent since experimentation with kenaf for pulp began. However, with frequent and intensive culture, kenaf may become subject to some of the serious diseases that affect cotton and okra.

In 1963 at Plymouth, N.C., damping-off caused by *Rhizoctonia solani* Kuehn resulted in rather severe thinning of stands of kenaf. Gray mold caused by *Botrytis cinerea* Pers. ex Fr. occurs rather frequently, especially during the late season when humidity is high and temperatures are low (fig. 9). Yield losses have been either insignificant or not accurately measured. This disease (see disease ratings in table 18, p. 21) contributed to lodging, especially among small plants in thick stands. If one or more lesions completely encircle the stem, parts above this area will die and lodging may occur at the point of infection. A severe infection by *Botrytis* sp. was reported in Florida and Peru in 1961 (*48*).

BN-35373

FIGURE 9.—Kenaf stems: *Left*, Healthy; *right*, severely infected with *Botrytis cinerea*.

Stalk discoloration after a killing freeze results from the development of various fungi, including saprophytic forms. This discoloration affects the bleaching requirements, and some flecking or spotting is difficult to remove from prepared pulps. Kenaf should be permitted to weather in the field for only a short time.

Anthracnose, a potentially serious disease caused by *Colletotrichum hibisci* Poll., was first reported from Java in 1927 and has since been reported from widely scattered areas of the world (*50*). This disease, which first appeared in Cuba and the United States in 1950, was considered a serious threat to the production of kenaf in these countries by 1952. Resistant selections were obtained from El Salvador (P.I. 207883), a variety noted for its variability. The varieties Everglades 71 and Everglades 41, resistant to the three known races of *C. hibisci*, evolved from El Salvador. The better known Cuban and Guatemalan varieties are also resistant. New breeding lines and introduced varieties need to be carefully tested for resistance before they are considered for commercial production.

Damping-off and root rot diseases will likely become more prevalent with continuous or intensive production of kenaf or of kenaf following cotton in a rotation. Thus, improvement programs should also include breeding for resistance to these common diseases.

Everglades 71 has shown slight tolerance to a disease-nematode complex in which the organisms *Pythium*, *Fusarium*, *Rhizoctonia*, and root-knot nematodes are involved (*73*). This tolerance is ineffective in soils heavily infested with root-knot nematodes.

No natural resistance has been found to southern blight, a potentially serious disease caused by *Sclerotium rolfsii* Sacc., but the disease has not been noted in experimental pulp plantings.

Although many insects may be found in a planting of kenaf, there has been little reported damage. Perhaps the most serious damage was observed on the Brazos River bottom near College Station, Tex., in 1967. Considerable defoliation resulted from a heavy infestation of salt-marsh caterpillars (*Estigmene acrea* Drury). These pests moved into the field slowly and stripped the foliage almost completely as they went. The Japanese beetle (*Popillia japonica* Newman) has caused some concern in Maryland and Pennsylvania plantings. Genung (*22*) reports that black and granulate cutworms [*Agrotis ipsilon* (Hufnagel) and *Feltia subterranea* (F.)] have been pests of kenaf in the Everglades area of Florida and that preplanting control is necessary to avoid possible heavy losses. Wilson and others (*73*) suggest the use of cutworm bait or a toxaphene-endrin (chlorinated camphene with 67 to 69 percent chlorine and 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-*endo*, *endo*-5,8-dimethanonaphthalene) spray immediately preplanting or postplanting.

Undoubtedly, the most serious production problem with kenaf is its suceptibility to soil nematodes. The most damaging species of nematodes are considered to be two root-knot species, *Meloidogyne incognita* (Kofoid and White) Chitwood and *M. incognita acrita* Chitwood. However, Winchester (*74*) presents evidence that kenaf is susceptible to several nematodes but indicates that symptoms of infection are more subtle than the characteristic root galling and stunted growth caused by the root-knot species.

Reaction of kenaf, roselle, and related species to root-knot species has been determined (*72*). None of the tested varieties of kenaf were resistant to nematodes. However, earlier work showed some variation in susceptibility, especially within lines (*53*). Individual plant selections from field tests exhibited more apparent tolerance than the parental lines from which the selections came.

Nematode infestation is usually at its worst on light, droughty soils of the Southeast and a seemingly vigorous, healthy crop suddenly may become unthrifty, defoliated, and unproductive. Root galling is shown in figure 10. Frequent planting of kenaf in rotation with cotton, tobacco, or other

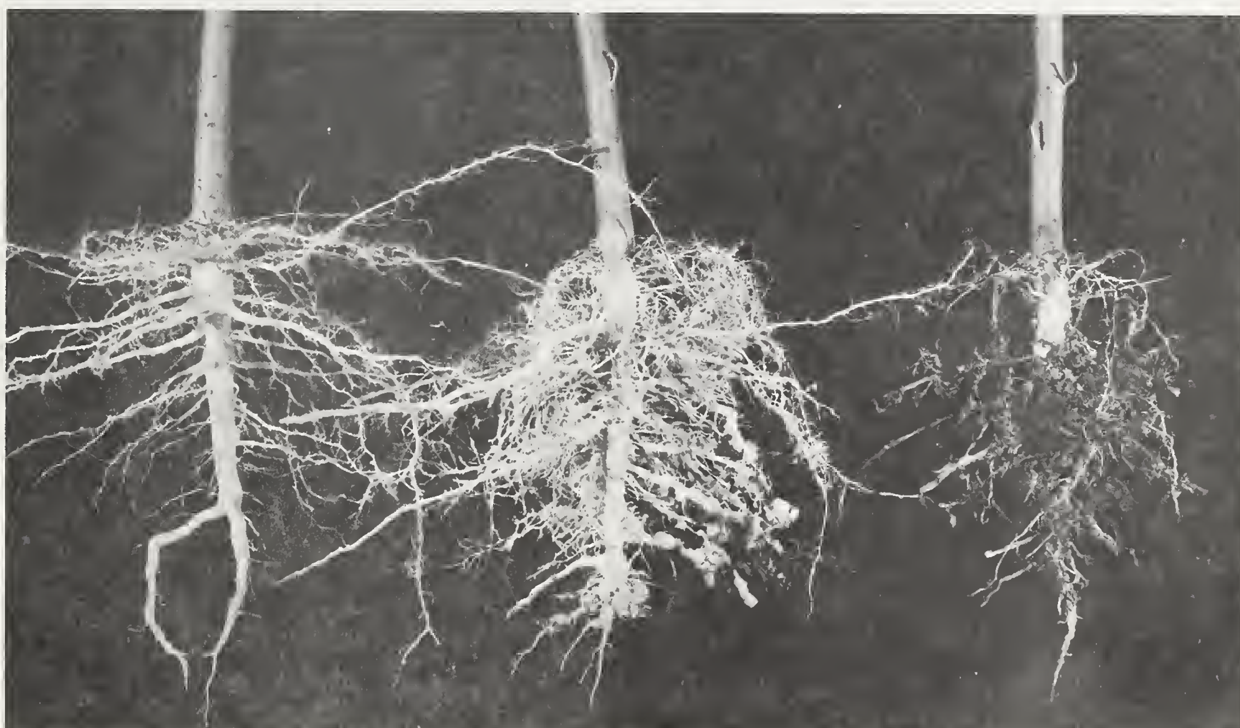
BN–35374

FIGURE 10.—Root-knot nematode galling on kenaf roots: *Left*, Healthy root; *center*, heavily galled root; and *right*, deterioration of root system because of galling and secondary fungi invasion.

nematode-susceptible crops should be discouraged. As far as possible, nematode-resistant crops and varieties should precede kenaf in a rotation. Fields known to be heavily infested should be avoided. Practices such as flooding and fallowing are sometimes effective but usually expensive (*52*). Rye was a better rotation crop with kenaf than with roselle (a resistant kenaf relative), corn, beans, or radishes; but field yields of kenaf following rye were lower than yields following fallow. More attention should be given to crop rotation.

The best solution to the nematode problem is to develop resistant varieties. Possible means of obtaining resistance in productive varieties are discussed in the section on crop improvement. (See p. 31.) While chemical control is generally considered uneconomical, more consideration to cost, effectiveness, and longevity of treatment of chemical nematicides is needed.

Seed Production

The Everglades, Cuban, and Guatemalan (except C–2032 and G–4) varieties require short days for floral initiation. Thus, because of the likelihood of frost during the short days of fall, seed production is limited to extreme southern locations in the United States. Seed has been produced successfully in southern Florida for several years, but seed quality has occasionally been poor because of unfavorable climatic conditions during maturation. Preliminary small-scale trials indicate that seed could be produced with good yields in the lower Rio Grande Valley area of Texas.

In southern Florida, seed increase plantings are made in mid-August to late August on sandy soils (*73*). Quality of seed has been poor from plantings on organic soils. Seeding at a rate of 10 to 15 pounds per acre is done with a grain drill. Seed yields from 7-inch rows were about the same as from 36-inch rows.

Harvesting should begin before the lower capsules begin dehiscing. A brownish coloration of capsules and a slight rattling of seed within the capsules indicate that the seed is ready for harvest. The simplest harvesting method is to direct combine the crop (plants will be 5 to 6 feet tall) and artificially dry the seed at 90° to 100° F. for 4 to 7 days. Seed yields of 300 to 600 pounds per acre are usual, but experimental yields in excess of 1,000 pounds have been reported. Yield improvement involving higher harvesting costs may be possible by harvesting the crop with a binder followed by shocking, field drying, and, subsequently, threshing.

Artificial drying of the seed may still be necessary. After drying, the seed should be thoroughly cleaned and stored under cool, dry (humidity less than 50 percent) conditions.

The U.S. Department of Agriculture's and the State experiment stations' involvement in seed production is limited to small-scale increases of particular varieties or selections that are to be included in cultural or breeding studies. Some commercial firms handle seed of the better known varieties, but only a limited amount of seed is actually produced in the United States. According to Dryer (*20*), production costs are higher and yields lower in the United States than in certain tropical countries such as Haiti. If the price and quality of the seed are right, the source is important only in relation to its reliability.

Limited amounts of seed of Everglades 71 and Everglades 41 for observational and experimental purposes are available from the New Crops Research Branch, Crops Research Division, U.S. Department of Agriculture, Beltsville, Md. 20705. When requesting seed for these purposes, please include you own ZIP code number.

Economics of Production and Harvesting

If kenaf is to become a successful new crop, two economic requirements must be met:

(1) The crop must be available to industry in a suitable form at a cost comparable to its value in relation to other raw materials.

(2) The crop must provide sufficient profit to the grower to make its production attractive, thereby providing incentive for sustained production.

We know that kenaf is technologically suitable for pulping; but since it is different from hardwoods and softwoods, processing procedures must be different for best results. However, the purpose of this discussion is not to consider processing procedures and costs. Rather, we are concerned about those costs associated with the production, harvesting, and delivery of the raw material to the mill site.

Trotter and Corkern (*55*, *56*) extensively assessed the economic potential of kenaf for selected farming areas in Alabama, Georgia, Mississippi, South Carolina, and Texas. Assumptions, relative costs, and other items for these areas should generally be applicable to northern Florida, Louisiana, and other areas in the general region not specifically covered in the assessment. Production and harvesting costs are given in table 24 and estimated net returns in figure 11.

TABLE 24.—*Estimated costs of producing and harvesting kenaf with regular farm equipment in the Piedmont area of Georgia* [1]

Cost item	Cost per acre with dry-matter yield of—		
	6 tons per acre	8 tons per acre	10 tons per acre
Production:			
Seed (8 pounds at $0.40 per pound)	$3. 20	$3. 20	$3. 20
Fertilizer [2]	18. 70	18. 70	18. 70
Lime	2. 74	2. 74	2. 74
Machinery and labor	10. 90	10. 90	10. 90
Other [3]	10. 71	10. 71	10. 71
Production cost per acre	46. 25	46. 25	46. 25
Harvesting:			
Machinery [4] and labor	14. 93	17. 42	19. 91
Hauling to mill site [5]	24. 00	32. 04	39. 96
Harvesting cost per acre	38. 93	49. 46	59. 87
Total cost per acre	85. 18	95. 71	106. 12
Total cost per ton	14. 20	11. 96	10. 61

[1] Costs based on 1966 prices.
[2] Fertilizer rate per acre of 500 pounds of 4–5.3–10 (nitrogen, phosphorus, and potassium) and 80 pounds nitrogen (from ammonium nitrate).
[3] Includes land charge, taxes, and interest on operating capital.
[4] Assumes the use of individually owned forage chopping equipment for harvesting.
[5] Based on costs for 2½-ton truck for a 20-mile haul, assuming 70 percent moisture in freshly chopped kenaf.

Source: Trotter and Corkern (*55*, *56*).

Harvesting, Handling, and Storage

The most successful harvesting method has been the use of heavy-duty forage choppers with row or cutter-bar headers (fig. 12). While some modifications are desirable, these machines are readily available and suitable for handling kenaf. Thus, the time and expense for development of new equipment is minimal. Uhr (*57*) lists four desirable features of forage choppers for harvesting kenaf: (1) Rugged design; (2) adjustments permitting close tolerance (10 to 25 one-thousandths of an inch) between cutter knives and the bedplate in order to obtain a clean cut; (3) an apron-type feeding mechanism rather than tooth-corrugated rolls (row headers); and (4) a topping device to remove the upper part of the plant ahead of the chopping operation. Harvesting research results in Texas suggest that the tolerance between knives and the bedplate should be 10 one-thousandths of an inch or less.

Forage choppers are satisfactory for harvesting kenaf, either green (high-moisture content) or air-dry (standing crop killed by frost or chemicals). Row headers can handle stalks of any size, but cutter-bar headers work best with stalks less than 10 feet tall. One possible problem with row headers is the height of cut adjustment. Because the stalks are largest at the base, the crop should be cut as close as possible to the ground for maximum yield.

Usually, closer cutter-knife clearance is possible with a cylinder-type chopper than with a flywheel-type chopper. Without close tolerance, a shredding or stranding of the bast fibers may occur. This gives a nonuniform cut and the stringy strands may wrap around the flywheel or cylinder shaft. The desired length of cut may vary, depending on the handling procedures and use of the chopped material. Length of cut can be adjusted by removing appropriate cutting knives and by changing speeds of the cylinder and feeding mechanism.

Other approaches to harvesting have been tried. In general, flail choppers and binders have been unsatisfactory. Regular farm balers will not satisfactorily bale finely chopped kenaf. We have not attempted to bale long chopped material. Balers will not efficiently pick up windrowed kenaf unless it has been crushed by a cutter crimper (*66*). Cutting and windrowing the crop presents the same hazards as encountered with hay; that is, possible introduction of dirt, quality decrease, and yield losses because of spoilage and bad weather. Leaf loss would, of course, be desirable with this handling system. Bales resulting from material hand fed into a baler are shown in figure 13.

In Texas studies (*66*), density (dry-weight basis) of bales was much greater than that of

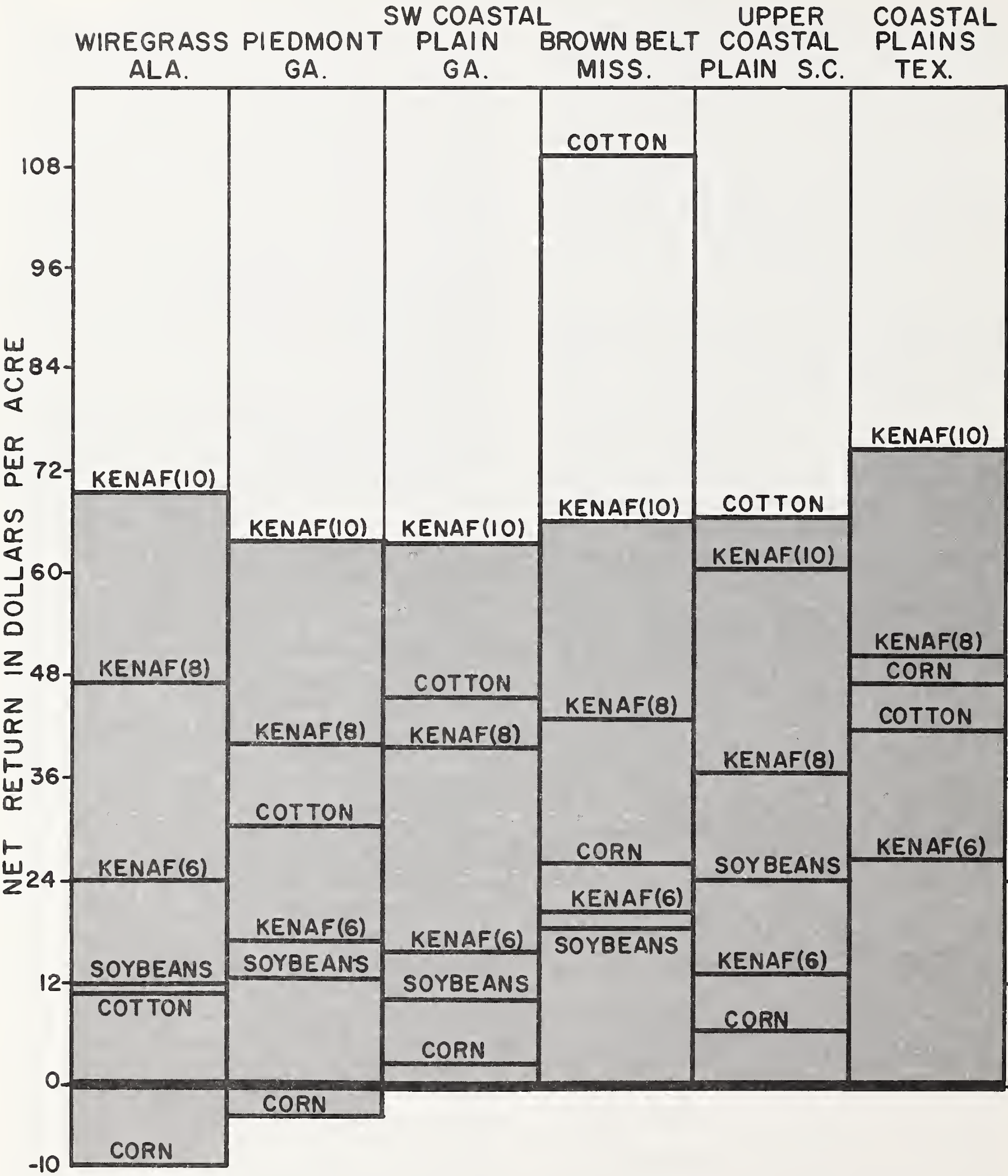

FIGURE 11.—Estimated net returns for kenaf at three yield levels (6, 8, and 10 tons per acre) compared with returns for corn, cotton, and soybeans in six agricultural areas. Adapted from Trotter and Corkern (*55, 56*). Kenaf returns based on a price of $17.00 per ton dry basis delivered to mill site.

material in bundles of whole stalks or after chopping stalks to different lengths. The estimated cost of chopping and hauling the material to the turn row was approximately $1.35 per ton. This system was much more economical than baling or using a binder.

Kenaf provides a bulky material, especially as whole stalks or in chopped form. After chopping, the question of appropriate handling and storage methods arises. More research is needed in this area, but we do have some results that are pertinent to the question and provide guidelines. With green chopped material, we think of bulk-storage methods such as those used for silage or sugarcane bagasse. In laboratory trials, pulping efficiency of ensiled chopped kenaf that was washed (neutralized) was good (*10*). These results indicate that storage under anaerobic conditions may be a useful way to preserve green and recently frost-killed kenaf. Partial dewatering of chopped kenaf to permit economical drying, or special storage is being studied (*9*, *11*). Alternative techniques to be considered for preservation of green chopped kenaf include the following:

(1) Storage in pit, trench, or bunker silos (fig. 14).
(2) Total submergence in water until time of processing.
(3) Storage in sealed and air-evacuated enclosures (cocoons) of plastic film or sheeting.
(4) Storage in covered piles or bins after artificial drying to a safe moisture level.
(5) Storage in open piles with or without addition of water by intermittent or continuous spraying.

The first three techniques offer possibilities for preservation under anaerobic conditions. The third technique, cocoon storage, has been applied to the preservation of both round wood and chips for pulp manufacture (*32*) and also for the preservation of green forage (*33*, *51*). Artificial drying as needed for the fourth technique probably would be economically prohibitive. Storage in open piles without controlled application of water appears unsatisfactory according to unpublished data accumulated by the Northern Utilization Research and Development Division at Peoria, Ill. Open storage with continuous wetting may have merit if chopped kenaf responds the same way as sugarcane bagasse (*31*) and pulpwood (*61*).

BN–35375

FIGURE 12.—A kenaf harvesting demonstration at Gainesville, Fla., on November 1, 1967. The one-row forage chopper is trailed by a self-unloading silage wagon.

Storage of kenaf may be preceded or followed by processing the green material to remove soluble substances and pith. Removal of these constituents improves efficiency of pulp preparation and quality of the pulp. Processing after wet storage would capitalize on the pith-loosening effects of microbial activity during the storage period.

Storage in either open or covered piles may prove satisfactory for material that has been air dried in the field before chopping, baling, or binding. There is some concern about the discoloration of stalks that remain in the field for a time after being frost killed. This discoloration sometimes results in the appearance of spots or specks in the pulp. Storage of bales inside, outside with cover, and outside without cover for a period of 18 months in Georgia did not adversely affect composition (*19*). Pulping evaluation of these materials is not yet complete.

BN-35376

FIGURE 13.—Bales of kenaf with a dry-weight density of approximately 11 pounds per cubic foot.

In summary, harvested kenaf will probably be hauled by the grower to the mill site or to a storage point. Although there are several possible harvesting methods, chopping the green or air-dried crop with a forage chopper appears the most feasible. Green material can be stored like silage or sugarcane bagasse, using bulk methods. Air-dried materials can be stored in large piles or stacks. According to Clark, Uhr, and Wolff (*13*), a preferred system of harvesting and storing to maintain quality has not been fully developed. Because of different climatic conditions and mill requirements, the system used will likely vary in different areas.

BN–35377

FIGURE 14.—A bunker silo in northern Florida from which corn silage is being removed for feeding.

Crop Improvement

Kenaf breeders have developed rapid-growing, high-yielding, anthracnose-resistant varieties that are amenable to mechanical harvesting and processing (*69*). Varieties with varying photoperiodic responses extend the harvesting period and areas of adaptation. These improvements, while tailored to kenaf as a cordage fiber source, are beneficial to the production of kenaf for pulp.

Little progress has been made in developing varieties that are resistant to root-knot nematodes and associated root-rot fungi. Susceptibility to these organisms is the most serious production problem confronting kenaf in the Southeast. Several approaches have been tried to obtain resistance. Two particularly promising approaches were in the early phases, but then the kenaf breeding program in southern Florida was discontinued. These approaches were: (1) Crossing a moderately resistant Kenyan accession (P.I. 292207) with susceptible cultivated strains and (2) crossing resistant roselle with susceptible kenaf strains (followed by doubling of the chromosome numbers in the hybrid). Seed of both the selfed and open-pollinated intraspecific crosses and the interspecific cross hybrids will be screened for possible nematode resistance.

Minton, Donnelly, and Shepherd (*38*, *39*) have devised a nematode-screening technique for vetch and lespedeza that is also satisfactory for kenaf. This technique involves greenhouse experiments in which nematode inoculum is added to the container at planting. Nematode species are tested separately. Plants are scored or rated according to the extent of root galling. This procedure permits the identification of resistant lines or individual plants. These lines are then used as a source of resistance in the development of productive varieties. The breeder needs to integrate resistance to diseases such as anthracnose and to other pests into his program for nematode resistance.

We feel that the area of adaptability could be broadened if less sensitivity to cool temperatures could be built into varieties. Early planting, regardless of the area, would be possible if cold tolerance and resistance to early seedling diseases were combined. In northern areas, where growing seasons are short, early planting would be very desirable. Cold tolerance would permit better use of the long days of the more northern latitudes.

For cordage fiber, varieties were sought which could be easily decorticated mechanically. Atchison (*4*) recommends studies on the separation and pulping of the two fiber types in kenaf stems, individually as well as in the mixture. For this, varieties that are easily decorticated would be desirable. When the whole stalk is to be utilized without any physical separation of fibers, varieties that do not decorticate well might be best. Certainly, standability or resistance to lodging is desirable, regardless of other characteristics.

Definitive procedures to assess pulping characteristics should be devised for use along with the development of distinct pulp varieties.

Although kenaf improvement through interspecific hybridization has been attempted, the work has not produced encouraging results except in the case of kenaf × roselle (*69*). Hybrids resulting from this cross have undergone some preliminary evaluation by Wilson and Menzel (*71*). The F_1 hybrids were triploid and varied in vigor and morphology but had similar flowers. Two of the F_1 hybrids showed high pollen fertility and gave rise to an F_2 population of 22 plants. The F_2 plants varied in vigor but were morphologically uniform. Wilson and Menzel discussed the possibilities for increasing the percentage of recovery of the F_1 interspecific hybrids and for synthesizing a hybrid variety that will prove useful for pulp and bast fiber. These hybrids are being screened for nematode reaction.

In inheritance studies pertinent to the selection

in inbred lines for composite varieties, heritability of variables was high (*40*). These variables included flowering date, stem diameter, plant height, percent fiber, and fiber weight.

The response of kenaf varieties to day length is an important factor in adaptation (*17, 59*). We use varieties that require short days (about 12½ hours of light) to flower so that maximum vegetative growth can be obtained. More consideration needs to be given to this factor in future breeding work.

Even though productive varieties are available, there appears to be considerable room for improvement, especially in terms of nematode root-rot resistance and development of distinct pulp types. Kenaf is grown in several countries as a cordage fiber crop and increasing interest in it as a new pulp source is expected. Thus, breeding will be complex, with varying requirements for the different areas and conditions.

Feed Value of Young Kenaf Plants and Tops

Although kenaf leaves and tender shoots or tops are sometimes eaten either raw or cooked, the use of young plants or tops for feed is a relatively new concept in the utilization of kenaf. Research in Florida showed that immature plants up to about 6 feet tall may contain as much as 20 percent protein (*76*). The chopped kenaf ensiled very efficiently with or without corn and results compared favorably with ensilability of other silage crops. The silage was very acceptable to a group of experimental heifers. Additional research in progress compares ensilability and feeding value of 6- and 8-foot crops with and without a preservative (*49*). The 6-foot crop involved in this research contained 24.3 percent protein. Crop recovery was not sufficient to permit a second cutting. In other tests, the amino acid pattern was similar to that of alfalfa (*8*).

The top leafy part of the kenaf plant is of no value for pulping. Thus, if kenaf is to be harvested fresh, this part of the plant should be removed and either returned to the ground or collected and used for feed. However, chopping equipment is not designed for this topping, chopping, and dual collecting operation. The economics involved in the equipment modification and the drying and handling of the tops must be considered. In the field-dried crop (after being killed chemically or by frost), most of the leaves and the top part of the stem drop off.

UTILIZATION AND PULPING CHARACTERISTICS

As a result of favorable agronomic and utilization assessment of kenaf, more detailed studies on composition, fiber dimensions, pulping processes, and use of kenaf–wood blends were conducted by the Northern Utilization Research and Development Division. Materials for use in these studies were provided by cooperating State experiment stations and the Crops Research Division.

Composition

Chemical composition was determined for kenaf grown in widely separated geographic areas in the United States (table 25). All samples except those from Florida were acquired from 2 weeks to 2 months after a killing frost. The length of the growing period varied considerably. More recent studies show that the growing period for kenaf

TABLE 25.—*Range in chemical composition of 50 samples of kenaf grown in widely separated geographic areas in the United States*

Characteristic	Minimum	Maximum	Mean
	Percent	*Percent*	*Percent*
Crude cellulose, M.E.A.[1]	45.1	58.3	52.8
Alpha cellulose	30.0	40.9	36.1
Solubility in 1% sodium hydroxide solution	25.8	39.7	31.9
Solubility in alcohol-benzene mixture	2.5	6.9	3.9
Ash	2.0	5.0	2.3
Lignin[2]	14.5	17.8	17.3
Pentosans[2]	20.1	21.5	20.8

[1] M.E.A. (monethanalamine) method: Nelson and Leming (*41*).
[2] 21 samples.

Source: Nieschlag, Nelson, and Wolff (*42*).

TABLE 26.—*Fiber dimensional characteristics and maceration yield of green and field-dried kenaf from 7 different locations and of selected reference materials*

Material tested and location	Crop year	Fiber length		Fiber width		Maceration yield	
		Bast	Woody core	Bast	Woody core	Bast	Woody core
Green kenaf:		*Millimeters*	*Millimeters*	*Microns*	*Microns*	*Percent*	*Percent*
Gainesville, Fla	1965	2. 42	0. 45	17. 0	33. 6	26. 2	32. 7
Peoria, Ill.[1]	1965	2. 32	. 48	15. 7	30. 1	22. 5	34. 0
Do	1966	2. 25	. 51	18. 4	34. 5	18. 0	28. 9
Do	1967	2. 91	. 68	17. 5	34. 4	19. 8	27. 6
Urbana, Ill	1957	2. 78	. 49	19. 2	37. 9	25. 2	29. 7
St. Gabriel, La	1967	2. 70	. 62	15. 7	32. 4	13. 3	30. 3
College Station, Tex	1965	2. 66	. 74	16. 9	25. 6	15. 6	41. 2
Field-dried kenaf:							
Experiment, Ga	1964	2. 80	. 61	14. 6	33. 3	20. 5	29. 3
Peoria, Ill.[2]	1965	2. 52	. 51	15. 9	30. 7	19. 8	36. 6
Do	1966	2. 28	. 45	17. 5	42. 3	21. 1	30. 2
Do	1967	2. 26	. 53	18. 9	37. 4	20. 4	30. 7
Urbana, Ill	1959	2. 34	. 63	17. 6	29. 6	15. 0	33. 0
Columbia, Mo	1958	2. 81	. 57	15. 8	31. 2	21. 0	35. 4
Reference materials:							
Softwoods [3]	--------	2. 9–6. 3		[4] 22–36		--------	--------
Southeastern slashpine [5]	--------	3. 1–5. 4		[6] 40–58		--------	--------
Hardwoods [3]	--------	. 85–1. 8		--------		--------	--------
Espartograss [7]	--------	. 99–2. 10		9. 7–11. 8		--------	--------
Bamboo [8]	--------	1. 36–4. 0		8. 7–22. 0		--------	--------
Sugarcane bagasse [9]	--------	1. 7		20. 0		--------	--------

[1] Days from planting to harvest were 150 in 1965; 138 in 1966; and 133 in 1967.
[2] Days from planting to harvest were 237 in 1965; 244 in 1966; and 158 in 1967.
[3] Source: Besley (*5*).
[4] Late wood.
[5] Source: Wangaard, Kellogg, and Brinkley (*62*).
[6] Early wood.
[7] Source: Nieschlag and others (*43*).
[8] Source: Clark, T. F. "Annual crop fibers and the bamboos." *In* Pulp and Paper Manufacture. v. II, Ed. 2. New York. 1969.
[9] Source: Lathrop (*29*).

plants considered for pulping should be at least 120 days (*13*). With the exception of pentosans content, there is a significant range in chemical values. This is partly attributable to location because plants develop much more rapidly in southern than northern locations. Larger plants grown in Florida had higher content of cellulose, pentosans, and lignin than shorter plants grown in Illinois, but the reverse was true for ash content (*13*). Sugar content of tops of plants from both locations was higher than that of lower parts of plants. Differences among varieties at the same location in the same year were usually minor. Wide differences in composition were noted between some locations, but replications were inadequate for statistical treatment of the data.

The crude cellulose and alpha cellulose contents in kenaf are about 1/6 less than those in softwoods and 1/7 less than those in hardwoods. However, the lignin content in kenaf is significantly lower than that in the woods. The pentosan content at about 20 percent in kenaf is double that in softwoods and nearly equal to that in hardwoods.

There are no great differences in composition of kenaf harvested either green or field dried after frost.

Fiber Dimensions

Kenaf stems contain two distinctly different types of fiber. The bast fiber is in the outer bark portion of the stem, whereas the shorter, woody fibers are in the thick inner core. Fiber dimensional data of green and field-dried (frost-killed) kenaf and of reference materials are given in table 26. The average length of the bast fibers is approximately 2.5 millimeters and that of the woody core fibers is 0.5–0.6.

The bast fiber size (average length, width, and

lumen diameter) was shown to be larger when harvested at 90 days than when harvested later (*13*). After 120 days, there is little change in size. The differences in fiber dimensions of stalks grown in Florida and in Illinois are minor and probably of little practical significance.

Fiber dimensional characteristics of kenaf stalks are essentially intermediate to those of the softwoods and the hardwoods. This in part accounts for the strength characteristics displayed by kenaf pulps in comparison with those displayed by wood pulps.

Evaluation of Pulping Processes

For a study of pulping processes at three levels of applied chemicals, kenaf from an Illinois planting was harvested about 6 weeks after frost (*12*). The pulping processes were soda, sulfate, and neutral sulfite with chemical concentrations of 15, 18, and 21 percent. The salient findings of this study were:

(1) Greater yields of pulp with less consumption of chemicals were realized with the neutral-sulfite process than the two alkaline (soda and sulfate) processes.

(2) Pulps prepared from the 21-percent chemicals required less chemicals for bleaching.

(3) In comparison with bleached commercial wood pulps at the same freeness level, the kenaf pulps were:

- (a) Superior to hardwood pulps in strength.
- (b) With the exception of resistance to tear, comparable in strength properties to softwood kraft and superior to softwood sulfite.
- (c) Less resistant to tear than softwood pulps, but more resistant than hardwood pulps.
- (d) About 200 ml. SR lower in initial freeness than the commercial wood pulps. This may hinder the use of kenaf pulps in some furnishes because slower draining pulps reduce paper machine productivity.

Kenaf–Wood Blends

Since papers and paperboards are seldom produced from a complete furnish of a single type of pulp, the properties of blends of kenaf and wood pulps were determined (*14*). Nine commercial wood pulps were selected for the studies. Physical properties of these pulps, a kenaf kraft pulp, and a kenaf neutral sulfite pulp are given in table 27. Composition of blends ranged from 0 to 100 percent for the kenaf pulps in 10-percent increments. In the blend of kenaf neutral sulfite pulp with a groundwood, a synergistic effect was observed for resistance to tear, expressed as tear factor. Opacity decreased with the addition of the kenaf pulp, but the decrease was less rapid than expected. Porosity, expressed as air resistance, remained at a low value until all of the groundwood had been removed from the blend. Groundwood pulp contributes little to folding endurance, but there was a significant improvement in folding endurance as soon as the blend contained 20 percent kenaf pulp.

Results indicate that papers with a reasonably wide range of properties may be made by blending selected kenaf pulps with selected wood pulps. Further studies of selected blends for specific types of paper are needed.

Applications for Kenaf in Paper

Since pulp products and papers exhibit a great variety of characteristics, we should expect kenaf pulps to find many feasible applications in a wide variety of pulps and papers. The use of kenaf fibers should not be considered a matter of direct substitution for a wood fiber because there are both similarities and differences in fiber properties of kenaf and wood. Thus, kenaf fibers should be tailored to make the maximum contribution to the product in which they are to be used. This indicates that each type product becomes a separate problem with respect to the use of kenaf fibers. Consideration must be given to functionality of the end product and that part that composition plays. Consumer specifications emphasize the service requirements and, to a lesser extent, composition. Many properties of paper—bursting strength (burst factor), caliper (thickness), folding endurance, finish (smoothness), opacity, water resistance, and tensile strength (wet or dry) expressed as breaking length—are frequently measured with respect to acceptance for use.

Kenaf pulps have good physical strength. Hand-

TABLE 27.—*Physical properties of handsheets prepared from kenaf and wood pulps*

Materials	Freeness SR	Bulk	Burst factor	Breaking length	Tear factor	Folding endurance	Opacity	Air resistance	Bonding index
	Ml.	*Cc./g.*	*(G./cm.²)/(g./m.²)*	*M.*	*G./(g./m²)*	*Schopper No.*	*Pct.*	*Sec./25 cc.*	*Pct.*
Kenaf kraft	600	1. 48	72. 1	11, 500	92. 9	1, 140	71. 0	403	87. 3
Kenaf neutral sulfite	500	1. 34	76. 9	11, 800	72. 7	1, 190	59. 8	1, 870	87. 3
Northeastern groundwood	500	2. 60	9. 9	2, 430	33. 8	0	98. 2	4	29. 2
Western softwood groundwood	500	2. 46	12. 8	3, 160	42. 0	1	98. 5	8	40. 8
Western unbleached softwood sulfite	820	1. 36	63. 6	10, 000	81. 8	960	74. 6	14	78. 6
Western softwood sulfite	800	1. 51	33. 8	5, 460	121	80	73. 5	3	47. 0
Southern softwood kraft	850	1. 57	74. 0	6, 980	169	1, 320	66. 5	1	49. 5
Do	750	1. 48	66. 4	9, 240	120	1, 580	62. 2	17	71. 0
Western softwood kraft	850	1. 71	47. 3	6, 840	212	950	73. 2	1	49. 5
Northeastern hardwood sulfite	600	1. 61	13. 2	2, 910	34. 1	2	86. 3	3	41. 6
Eastern hardwood kraft	600	1. 41	25. 0	4, 690	42. 3	10	81. 5	5	61. 2
Southern hardwood kraft	750	1. 58	34. 1	5, 700	75. 2	56	78. 4	2	54. 2

Source: Clark and Wolff (*14*).

sheets and experimental papers have had good bursting strength, tensile strength, folding endurance, and surface finish. Fiber dimensions contribute to these properties. Effective length of the bast and woody fibers together is reasonably good and the narrow width of the bast provides a smooth surface. Because of their relatively thin cell walls, the fibers tend to collapse to flat ribbons during paper formation and this behavior thereby provides a high degree of flexibility in the sheets. This behavior also contributes to a high bonding index and high folding endurance. Narrow fibers reduce surface roughness and the resulting sheets have good printing and writing qualities. Finish involves not only the fibers but also the treatment that is given the pulps before they are run on a machine. Opacity is governed in part by the type of fiber and also by the refining treatment given the pulps. For translucent papers, kenaf pulps may have an advantage because of their tendency to hydrate easily during refining. Thus, in applications where high opacity is desired, a minimum of refining would be required.

No specific paper has been indicated as being a preferred type in which to incorporate kenaf fibers. This can be determined only through trial and error. Kenaf should prove to be a versatile raw material for various pulping applications.

Results of utilization investigations are very encouraging and thereby greatly enhance the potential for kenaf to become an economically important new crop for the United States.

LITERATURE CITED

(*1*) ANONYMOUS.
1966. WOOD: WORLD TRENDS AND PROSPECTS. Unasylva 20 (80–81), 136 pp., illus.

(*2*) ASSOCIATION OF OFFICIAL SEED ANALYSTS.
1960. RULES FOR TESTING SEEDS. Assoc. Off. Seed Anal. Proc. 49 (2): 25.

(*3*) ATCHISON, J. E.
1967. WORLD FIBER SOURCES AND PROSPECTS OF THE DEVELOPING NATIONS. Paper Trade Jour. 151 (9): 52–53.

(*4*) ———
1968. PRETREATMENTS FOR KENAF. First Conf. on Kenaf for Pulp Proc. Gainesville, Fla. (1967), pp. 83–85.

(*5*) BESLEY, LOWELL.
1960. RELATIONSHIP BETWEEN WOOD FIBRE PROPERTIES AND PAPER QUALITY. Pulp Paper Mag. Canada 61 (7): 136–140, 146, 148.

(*6*) BROMLEY, W. S.
1966. SOUTHERN PULPWOOD "EXPLOSION." Pulpwood Prod. and Saw Mill Logging 14 (2): 12, 14, 16, 20, 22, 24, illus.

(*7*) BURNSIDE, O. C., AND WILLIAMS, J. H.
1968. WEED CONTROL METHOD FOR KINKAOIL, KENAF, AND SUNN CROTALARIA. Agron. Jour. 60: 162–164.

(*8*) CAHILLY, G. M.
1968. POTENTIAL VALUE OF KENAF TOPS AS A LIVESTOCK FEEDSTUFF. First Conf. on Kenaf for Pulp Proc. Gainesville, Fla. (1967), p. 48.

(*9*) CASSELMAN, T. W.
1968. MECHANICAL DEWATERING OF FORAGE CROPS. First Conf. on Kenaf for Pulp Proc. Gainesville, Fla. (1967), pp. 59–64, illus.

(*10*) CLARK, T. F.
1968. PULPING OF GREEN KENAF FROM ANAEROBIC STORAGE: EXPLORATORY TESTS. First Conf. on Kenaf for Pulp Proc. Gainesville, Fla. (1967), pp. 73–82.

(*11*) ———
1968. HANDLING AND STORAGE OF KENAF. First Conf. on Kenaf for Pulp Proc. Gainesville, Fla. (1967), p. 65.

(*12*) ——— NELSON, G. H., NIESCHLAG, H. J., AND WOLFF, I. A.
1962. A SEARCH FOR NEW FIBER CROPS. V. PULPING STUDIES ON KENAF. TAPPI 45 (10): 780–786, illus.

(*13*) ——— UHR, S. C., and WOLFF, I. A.
1967. A SEARCH FOR NEW FIBER CROPS. X. EFFECT OF PLANT MATURITY AND LOCATION OF GROWTH ON KENAF COMPOSITION AND PULPING CHARACTERISTICS. TAPPI 50 (11): 52A–56A, illus.

(*14*) ——— and WOLFF, I. A.
1962. A SEARCH FOR NEW FIBER CROPS. VI. KENAF AND WOOD PULP BLENDS. TAPPI 45 (10): 786–789, illus.

(*15*) CORKERN, R. S.
1964. KENAF—A BIBLIOGRAPHY, 1950–1962. U.S. Dept. Agr., Econ. Res. Serv. ERS–153, 16 pp.

(*16*) CRANDALL, B. S.
1965. PERFORMANCE OF KENAF VARIETIES UNDER VARYING CLIMATIC CONDITIONS. Second Internatl. Kenaf Conf. Proc. Palm Beach, Fla. (1964), pp. 202–203.

(*17*) ——— CABREA, A. P., and SUMMERS, T. E.
1961. DEVELOPMENT OF PHOTO-PERIOD INSENSITIVE, DISEASE RESISTANT KENAF VARIETIES FOR THE CARIBBEAN AREA. Carribbean Region of the Amer. Soc. Hort. Sci. Proc. 5: 76–79.

(*18*) CRANE, J. C.
1947. KENAF—FIBER-PLANT RIVAL OF JUTE. Econ. Bot. 1 (3): 334–350.

(*19*) CUMMINS, D. G.
1968. KENAF STORAGE. First Conf. on Kenaf for Pulp Proc. Gainesville, Fla. (1967), p. 58.

(*20*) DRYER, J. F.
1968. KENAF SEED VARIETIES. First Conf. on Kenaf for Pulp Proc. Gainesville, Fla. (1967), pp. 44–46.

(*21*) FIKE, W. T.
1968. ROW-WIDTH AND PLANT-DENSITY STUDIES WITH KENAF IN NORTH CAROLINA. First Conf. on Kenaf for Pulp Proc. Gainesville, Fla. (1967), p. 36.

(*22*) GENUNG, W. G.
1965. INSECTS ASSOCIATED WITH KENAF IN FLORIDA. Second Internatl. Kenaf Conf. Proc. Palm Beach, Fla. (1964), pp. 139–145.

(*23*) GRAY, J. L.
1968. SOME TRENDS IN PRODUCT DEMAND, WOOD SUPPLY AND COST WHICH ENCOURAGE DEVELOPMENT OF NONWOOD SOURCES OF FIBER FOR PULPING. First Conf. on Kenaf for Pulp Proc. Gainesville, Fla. (1967), pp. 1–9.

(*24*) HIGGINS, J. J., HAUN, J. R., and KOCH, E. J.
1964. LEAF DEVELOPMENT: INDEX OF PLANT RESPONSE TO ENVIRONMENTAL FACTORS. Agron. Jour. 56 (5): 489–492, illus.

(*25*) KARBASSI, PARVIS, and KILLINGER, G. B.
1966. EFFECT OF MACRONUTRIENTS ON GROWTH OF KENAF. Soil and Crop Sci. of Fla. Proc. 26: 226–230.

(*26*) KILLINGER, G. B.
1965. KENAF, A POTENTIAL PAPER-PULP CROP FOR FLORIDA. Second Internatl. Kenaf Conf. Proc. Palm Beach, Fla. (1964), pp. 54–57.

(27) ———
1965. KENAF, A POTENTIAL PAPER-PULP CROP FOR FLORIDA. Fla. Agr. Expt. Sta., Sunshine State Agr. Res. Rpt. 10 (2): 4–5, illus.

(28) ———
1968. SOME CULTURAL ASPECTS OF KENAF (HIBISCUS CANNABINUS L.) WHEN GROWN IN NORTH CENTRAL FLORIDA. First Conf. on Kenaf for Pulp Proc. Gainesville, Fla. (1967), pp. 37–39.

(29) LATHROP, E. C.
1954. ECONOMIC FACTORS TO BE CONSIDERED IN THE USE OF SUGARCANE BAGASSE AS A RAW MATERIAL FOR PULP AND BOARD MANUFACTURE. U.S. Dept. Agr., Agr. Res. Serv. ARS 71–2, 42 pp., illus.

(30) MCCANN, L. P.
1952. KENAF (HIBISCUS CANNABINUS L.), A BIBLIOGRAPHICAL SURVEY. U.S. Dept. Agr. Bibliog. Bul. 17, 20 pp., illus.

(31) MACDONALD, T.
1963. RITTER BAGASSE PROCESS. Pulp and Paper Internatl. 5 (10): 45–47, illus.

(32) MCKEE, J. C., and DANIEL, J. W.
1966. LONG TERM STORAGE OF PULPWOOD IN SEALED ENCLOSURES. TAPPI 49 (5): 47A–50A, illus.

(33) MANN, D. H.
1967. SILAGE IN A PLASTIC BAG. Farm Quart. 22 (1): 90–91, 148–150, illus.

(34) MENZEL, M. Y.
1965. CYTOLOGICAL STUDIES WITH KENAF. Second Internatl. Kenaf Conf. Proc. Palm Beach, Fla. (1964), pp. 134–138.

(35) ——— and WILSON, F. D.
1961. CHROMOSOMES AND CROSSING BEHAVIOR OF HIBISCUS CANNABINUS, H. ACETOSELLA, AND H. RADIATUS. Amer. Jour. Bot. 48 (8): 651–657.

(36) ——— and WILSON, F. D.
1963. CYTOTAXONOMY OF TWELVE SPECIES OF HIBISCUS SECTION FURCARIA. Amer. Jour. Bot. 50 (3): 262–271.

(37) ——— and WILSON, F. D.
1966. HYBRIDS AND GENOME RELATIONS OF HIBISCUS SABDARIFFA, H. MEEUSEI, H. RADIATUS AND H. ACETOSELLA. Amer. Jour. Bot. 53 (3): 270–275.

(38) MINTON, N. A., DONNELLY, E. D., and SHEPHERD, R. L.
1966. REACTION OF VICIA SPECIES AND F_5 HYBRIDS FROM V. SATIVA X V. ANGUSTIFOLIA TO FIVE ROOT KNOT NEMATODE SPECIES. Phytopathology 56 (1): 102–107, illus.

(39) ——— DONNELLY, E. D., and SHEPHERD, R. L.
1966. REACTION OF VARIETIES AND BREEDING LINES OF SERICEA LESPEDEZA TO FIVE ROOT KNOT NEMATODE SPECIES. Phytopathology 56 (2): 180–182, illus.

(40) NELSON, E. G. and WILSON, F. D.
1965. INHERITANCE IN KENAF AS RELATED TO SELECTION OF INBRED LINES FOR COMPOSITE VARIETIES. U.S. Dept. Agr. Tech. Bul. 1319, 28 pp.

(41) NELSON, G. H., and LEMING, J. A.
1957. EVALUATION OF MONOETHANOLAMINE METHOD OF CELLULOSE DETERMINATION FOR AGRICULTURAL RESIDUES. TAPPI 40 (10): 846–850, illus.

(42) NIESCHLAG, H. J., NELSON, G. H., and WOLFF, I. A.
1961. A SEARCH FOR NEW FIBER CROPS. IV. KENAF COMPOSITION. TAPPI 44 (7): 515–516.

(43) ——— NELSON, G. H., WOLFF, I. A., and PERDUE, R. E.
1960. A SEARCH FOR NEW FIBER CROPS. TAPPI 43 (3): 193–201, illus.

(44) ORSENIGO, J. R.
1965. WEED CONTROL IN KENAF. Second Internatl. Kenaf Conf. Proc. Palm Beach, Fla. (1964), pp. 177–187.

(45) PATE, J. B.
1953. RESISTANCE IN KENAF TO COLLETOTRICHUM HIBISCI. Phytopathology 43 (11): 647–648, illus.

(46) ——— and JOYNER, J. F.
1958. THE INHERITANCE OF A MALE STERILITY FACTOR IN KENAF, HIBISCUS CANNABINUS L. Agron. Jour. 50 (7): 402–403.

(47) ——— and SUMMERS, T. E.
1955. REACTION OF KENAF INTRODUCTIONS AND SELECTIONS TO RACES OF COLLETOTRICHUM HIBISCI. U.S. Dept. Agr. Plant Disease Rptr. 39 (10): 776–778.

(48) PEREZ, J. M., and SUMMERS, T. E.
1963. A BOTRYTIS DISEASE OF KENAF. U.S. Dept. Agr. Plant Disease Rptr. 47 (3): 200–201, illus.

(49) POWELL, G. W. and WING, J. M.
1968. KENAF AS SILAGE. First Conf. on Kenaf for Pulp Proc. Gainesville, Fla. (1967), p. 49.

(50) PRESLEY, J. T., SUMMERS, T. E., and CRANDALL, B. S.
1965. THE ANTHRACNOSE DISEASE OF KENAF AND ITS CONTROL. Second Internatl. Kenaf Conf. Proc. Palm Beach, Fla. (1964), pp. 119–133, illus.

(51) SPRAGUE, M. A., and TAYLOR, B. B.
1966. PRESERVATION OF SILAGE IN PLASTIC BAGS—A NEW METHOD FOR RESEARCH WITH FORAGES. IX Internatl. Grassland Cong. Proc. v. I, pp. 637–643, illus.

(52) SUMMERS, T. E.
1965. CONTROL OF ROOT-KNOT NEMATODES AND ROOT DISEASES OF KENAF. Second Internatl. Kenaf Conf. Proc. Palm Beach, Fla. (1964), pp. 101–104.

(53) Summers, T. E., Pate, J. B., and Wilson, F. D.
1958. extent of susceptibility within kenaf, hibiscus cannabinus l., to root-knot nematodes. U.S. Dept. Agr. Plant Disease Rptr. 42 (5) : 591–593, illus.

(54) Toole, E. H., Toole, V. K., and Nelson, E. G.
1960. preservation of hemp and kenaf seed. U.S. Dept. Agr. Tech. Bul. 1215, 16 pp.

(55) Trotter, W. K., and Corkern, R. S.
1968. economics of kenaf for pulp in the south: a preliminary view. First Conf. on Kenaf for Pulp Proc. Gainesville, Fla. (1967), pp. 13–31, illus.

(56) ——— and Corkern, R. S.
1968. kenaf economics: a preliminary view. TAPPI 51 (10) : 99A–103A, illus.

(57) Uhr, S. C.
1968. kenaf harvesting. First Conf. on Kenaf for Pulp Proc. Gainesville, Fla. (1967), pp. 56–57.

(58) United States Department of Agriculture.
1968. proceedings—first conference on kenaf for pulp. Gainesville, Fla. (1967), 114 pp., illus.

(59) United States Department of State.
1959. proceedings—world conference on kenaf. Havana, Cuba (1958), 288 pp., illus.

(60) ———
1965. proceedings—second international kenaf conference. Palm Beach, Fla. (1964), 288 pp., illus.

(61) Volkman, D.
1966. water spray storage of southern pine pulpwood. TAPPI 49 (7) : 48A–53A, illus.

(62) Wangaard, F. F., Kellogg, R. M., and Brinkley, A. W.
1966. variation in wood and fiber characteristics and pulp sheet properties of slash pine. TAPPI 49 (6) : 263–277.

(63) White, G. A., and Higgins, J. J.
1965. growing kenaf for paper. Second Internatl. Kenaf Conf. Proc. Palm Beach. Fla. (1964), pp. 27–40. illus.

(64) ——— and Higgins, J. J.
1968. review of recent agronomic results. First Conf. on Kenaf for Pulp Proc. Gainesville, Fla. (1967), p. 43.

(65) Whiteley, E. L.
1968. seed treatment and planting equipment. First Conf. on Kenaf for Pulp Proc. Gainesville, Fla. (1967), pp. 32–33.

(66) Wilkes, L. H., Hobgood, Price, and Whiteley, E. L.
1969. evaluating systems of harvesting and handling kenaf as a source of paper pulp. ASAE Trans. 12 (1) : 34–38, illus.

(67) Williams, J. H.
1966. influence of row spacing and nitrogen levels on dry matter yields of kenaf (hibiscus cannabinus l.) Agron. Jour. 58: 166–168.

(68) Wilson, F. D.
1965. improvement of kenaf through interspecific hybridization. Second Internatl. Kenaf Conf. Proc. Palm Beach, Fla. (1964), pp. 213–221, illus.

(69) ———
1968. kenaf breeding. First Conf. on Kenaf for Pulp Proc. Gainesville, Fla. (1967), pp. 11–12.

(70) ——— and Menzel, M. Y.
1964. kenaf (hibiscus cannabinus), roselle (hibiscus sabdariffa). Econ. Bot. 18 (1) : 80–91, illus.

(71) ——— and Menzel, M. Y.
1967. innterspecific hybrids between kenaf (hibiscus cannabinus) and roselle (h. sabdariffa). Euphytica 16: 33–44, illus.

(72) ——— and Summers, T. E.
1966. reaction of kenaf, roselle, and related species of hibiscus to root knot nematodes. Phytopathology 56 (6) : 687–690, illus.

(73) ——— Summers, T. E., Joyner, J. F., and others.
1965. 'everglades 41' and 'everglades 71'—two new varieties of kenaf (hibiscus cannabinus l.) for fiber and seed. Fla. Agr. Expt. Sta. Cir. S–168, 12 pp., illus.

(74) Winchester, J. A.
1965. kenaf nematodes. Second Internatl. Kenaf Conf. Proc. Palm Beach, Fla. (1964), pp. 188–189.

(75) ———
1965. cultural control of plant nematodes. Second Internatl. Kenaf Conf. Proc. Palm Beach, Fla. (1964), pp. 190–196.

(76) Wing, J. M.
1967. ensilability, acceptability and digestibility of kenaf. Feedstuffs 39 (29) : 26, illus.

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